RADIOLOGY

AS A DIAGNOSTIC AID IN

CLINICAL SURGERY

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INTRODUCTION

This book is intended for surgeons Most books on radiology are written for radiologists and as such include many diagnostic minutiae considerable technical detail and much that is academic There have been many excellent standard text books produced along these lines Recent advances in radiology are often technical in nature and may have little application to the day to day work of the practising surgeon and therefore lie outside the sphere of this book

The emphasis here is on clinical problems and the writer has principally selected his subjects from those on which his surgical colleagues have consulted him in daily practice in a busy teaching hospital In particular an attempt has been made to emphasize the scope and limitations of radiology as a diagnostic aid when the surgeon is faced with any particular clinical circumstances

Radiology is merely graphic pathology It is a photograph in time of a state of affairs at that point in time It has an advantage over morbid anatomy in that the subject can be considered while the patient is still alive and an advantage over histology by biopsy in that the whole of a pathological condition can often be viewed rather than a small operative specimen It has a further advantage over both in that the course of a condition can be observed by serial X ray examinations and so the progression or resolution of the disease process can be assessed It also has limitations in that it is dependent on a difference in tissue densities a contrast between adjacent structures for a demonstration of those structures This does not always exist and though it is possible in many instances to introduce contrast in the form of contrast media this can not always be performed or even if it is it does not always provide a diagnosis

Interpretation must be based on a thorough knowledge of the normal and of normal variations against this background changes can be interpreted in terms of pathology provided again a clear knowledge exists of the pathological processes which may occur in any anatomical site taking into consideration the age and sex of the patient The inexperienced tend to diagnose as abnormal what are either anatomical variations or are variations due to technical factors Interpretation is essentially the function of the trained radiologist trained in the technical aspects of this work as well as in the fundamentals of interpretation expounded here Yet it is essential for the surgeon to know the scope and limitations of this branch of medicine if he is to obtain all the help that can be made available and if he is to avoid the pitfalls that too implicit a faith in the power of radiology may produce

It is important therefore for the surgeon to realize that the greatest benefit will come from frequent personal contact and consultation with the radiologist and to realize that the radiologist by virtue of his training and experience is best adapted to decide how to conduct a radiological examination and how to derive the maximum information from the radiological investigation of any particular clinical problem This however the radiologist can only do if he is aware of the clinical problem and is not merely asked to conduct an examination as a technical feat It should therefore be the aim of the surgeon requesting an X ray examination to provide the necessary clinical details of the case to be investigated rather than to give instructions of technical requirements and then to leave the radiologist to decide how to conduct it

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CHAPTER 1

EMERGENCY WORK

In any general hospital in an industrial town it is common for up to one-quarter of the total number of X ray investigations to be emergency cases mainly referred from the casualty department That does not imply that a quarter of the work of such an X ray department is casualty work for of course many of these investigations are of a minor nature quickly carried out Nevertheless it is an indication of the importance of the aid that X ray facilities are required to provide in this field of medical practice It may be argued that much of this work is of doubtful necessity or is only necessary for medico legal purposes and that doctors more experienced than casualty house officers would call on this service far less yet while it is true that those experienced in such work rely more on their clinical judgement casualty house officers must gain their clinical experience and while doing so must have some clinical freedom Further it must not be forgotten that in those cases where inexperienced doctors have relied on their clinical judgement and have subsequently been proven to be wrong the judgement of the courts has often gone hard against them if they have failed to have the patient X rayed

(1) Fractures

Radiological procedure for the demonstration of and control of the treatment of fractures has become an integral part of surgical practice This is best discussed as (a) *the investigation of suspected fractures* (b) *the demonstration of the type and extent of clinically obvious fractures* (c) *the control of reduction or other operative procedures and* (d) *the assessment of progress*

(*a*) The treatment of any fracture imposes on the patient a degree greater or lesser in extent of immobility The treatment of a sprain or soft tissue injury while still requiring immobilization is generally of a shorter duration To treat a fracture as a sprain or as a simple soft tissue injury may especially in children or if articulating surfaces are involved have serious results Radiological demonstration or exclusion of bony injury has thus become a procedure of considerable social and economic significance to the individual and to society

In children the confirmation of a greenstick fracture may be of merely academic interest while the failure to detect one of the commonest of injuries slipped radial epiphysis with a posterior marginal fracture of the radial metaphysis may have long reaching effects on the individual s

ability to play games or even to write In this latter injury, as the epiphysis is displaced backwards the blood vessels in the growing epiphyseal cartilage are torn causing a local haematoma and disorganizing the zone of bone growth Yet unless the films are of good quality and this type of fracture is specifically sought it is easy to overlook it

Similarly, in the adult fractures of the carpal scaphoid may avoid radiological detection In the early stages except in gross cases fracture of the scaphoid is really a clinical diagnosis and suspected cases should *in the absence of radiological confirmation be treated on clinical grounds* If the bone is in fact fractured and yet no fracture line can be detected on the X ray film immediately after the injury the fracture line will be detectable 14 to 17 days after the injury when the wrist is out of plaster This is because in the intervening period the hyperaemia resulting from the injury causes absorption of bone trabeculae from the adjacent edges of the fracture If at this period after the injury no fracture line is visible then there has been no bony injury and the wrist injury can be treated accordingly It is wise therefore not to lose the advantage of treatment during the intervening period in suspected cases for continued movement may prolong the necessary period of treatment or even cause irreparable damage

(*b*) If clinically obvious fractures are to be satisfactorily treated then it is essential that the surgeon should know the exact site of the fracture the type its relationship to surrounding structures involvement of articular surfaces whether or not it is intra capsular the type and extent of deformity whether shortening or distraction exists the presence of comminution and the existence of any underlying bony disease All this information can be provided by X ray examination

In the investigations of these problems there are certain maxims which must be observed It should always be routine practice to take two films of the injured part the one at right angles to the other Not only will this practice lead to the detection of crack fracures not readily visible in one projection but it will also demonstrate the full extent of any deformity resulting from the fracture deformity not always suspected from the clinical examination or from a single frontal projection of the injured part (see Fig 1) Furthermore the whole length of an injured bone and the adjacent joints should always be included in the survey films It is often false economy to examine only the affected part of the bone For example fractures of the lower third of the tibia often have associated with them a fracture of the neck of the fibula and in midshaft fractures of the ulna it may be calamitous to the patient to miss the other component of a Monteggia fracture namely dislocation of the head of the radius because of an inadequate radiographic examination

(*c*) After reduction of any fracture of a long bone or of a fracture dislocation whether the reduction is maintained by a splint or by

plaster it is normal procedure to re X ray in order to confirm that the reduction achieved is clinically acceptable It is sometimes stated that radiological opinions on such examinations are unnecessary this however is not true In departments where mutual trust and reliance exists radiological opinions on these examinations will be clear reports of fact occasionally drawing the attention of the surgeon to some feature that he had overlooked they will at all times avoid comment or judgement on the result for this lies entirely within the realm of clinical judgement as to what is regarded as a satisfactory or acceptable state of affairs taking into consideration such matters as the clinical state of the patient age function etc The fact that all such examinations are seen and reported on by a radiologist will also have the effect of maintaining the technical standard of the radiography

Some injuries are such that they require X ray control during the operative procedure of reduction or treatment For example reduction of fractures of the neck of the femur and their fixation by nail or screw can only be achieved under X ray control There are now many variations of the type of nail or screw used and there are many variations on the method of ensuring that it enters the neck of the femur in the right direction and that the right length of nail or screw is used However most methods include the following basic fundamentals —

(i) Reduction of the fracture

(ii) X ray of the hip in two planes antero posterior and lateral to confirm the satisfactory reduction

(iii) Insertion of a guide wire from below the greater trochanter through the femoral neck into the femoral head

(iv) X ray examination of this in an antero posterior plane to confirm the direction of the guide wire and show its end so that a nail or screw of the correct length can be selected

(v) X ray examination in an antero posterior plane of any further guide wires that it may subsequently be necessary to insert if the direction of the first one is incorrect

(vi) Insertion of the nail or screw and subsequent plate fixation

(vii) X ray demonstration in two planes antero posterior and lateral of the site of the nail or screw

From this it is obvious that the radiological control has a great part to play A dark room with rapid processing facilities must be adjacent to the theatre so that there is the minimum of delay in the films being available for viewing Also it is more satisfactory to have two mobile X ray sets in the theatre one set up for the lateral projections and one for the overhead projection Similarly some form of cassette tunnel or holder that will fit to the operating table is required for both projections

(*d*) The assessment of repair by radiological means requires a full understanding of the processes of repair

In the early stages of repair the condition is one of exudate partly fluid partly clotted haematoma between the bone ends under the raised periosteum and in adjacent soft tissues, undergoing organization A rapidly growing hyperaemic fibrous cellular granulation tissue growing from the bone ends surrounds and invades the haematoma Hypertrophic cartilage growing in the marrow space and beneath the periosteum marks the early stage of callus formation The fibroblastic granulation tissue between the bone ends by which continuity has already been established is then invaded and replaced by these cartilage cells The hyperaemia then diminishes and calcification of the cartilaginous matrix takes place This is the stage of union by callus During the later stages of the laying down of the hypertrophic cartilage osteoblastic activity is considerable and bone is laid down in the cartilaginous matrix this gradually maturing to fully formed but irregular bone which in due course is replaced by lamellar bony trabeculae along the lines of stress Periosteal new bone is absorbed and the bone remoulded by normal osteoclastic and osteoblastic activity and finally fat and marrow cells re appear in the marrow space

Radiology is merely a graphic representation of the pathological process but as always in bone conditions the radiological representation lags behind the clinical state In the early stages of fracture repair organizing blood clot and cartilage growth casts no shadow Hyperaemia in bone however always produces a local osteoporosis and so after seven to ten days the adjacent bone ends of the fragments are seen to become slightly osteoporotic and a little less well defined Then as calcification in the cartilaginous matrix takes place this becomes visible usually in a zone rather wider than the normal tubular form of the continuous bone This calcifying callus is not visible until three or more weeks have elapsed In due course as osteoblastic activity progresses trabecular bone replaces this calcifying callus and at the same time osteoclastic resorption reshapes the callus and tubulation is affected Radiological union has not taken place until continuous bony trabeculae can be seen bridging the gap and this may take three to four months The age of the patient affects very much the rate of the later stages union taking place sooner in younger subjects Similarly slow union may be due to deviation of the blood supply from one fragment of the bone or due to excessive traction in maintaining reduction of the fracture The former may be anticipated from the anatomical site of the fracture as demonstrated radiologically while distraction of the bony fragments demonstrated on the post reduction films may indicate the possibility of the latter In all cases clinical evidence of union occurs much sooner than radiological union

If immobilization of the fracture has been inadequate repeated movement causes recurrent local haemorrhage increase in the size of

the haematoma and increase in the local hyperaemia of the bone ends attempting to initiate the process of repair This excessive hyperaemia will produce radiologically a more marked resorption and osteoporosis of the bone ends which is readily recognized on the radiograph after two to three weeks Invasion of the granulation tissue so formed by hypertrophic cartilage cells leading to callus formation shows radio logically as a large mass of calcifying callus Such a mass of callus is usually an indication that immobilization has not been entirely effective

Repeated movement with decalcification of the bone ends may, of course lead to delayed union and osteoporosis thus shown is to be regarded as a danger signal and an indication that unless immobilization is more effective prolonged treatment may be necessary If delayed union is allowed to continue it may lead to established non union In this event the gap between the bone ends becomes clearly defined and the edges of the bony fragments become quite clear and even sclerotic (see Fig 1) These surfaces become smooth the gap between being

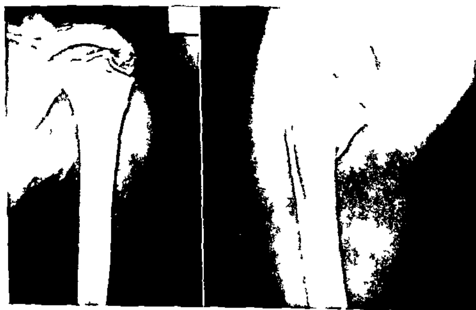


FIG 1 A P and vertical views of the left shoulder showing a fracture of the surgical neck Alignment in the frontal projection appears satisfactory but the other projection shows that angulation exists

filled by fibrous tissue serum loculation may take place in this cicatricial mass forming a false joint or pseudarthrosis

In the normal control of repair and review of progress the bone may be X rayed through plaster Calcifying callus can usually be seen through the shadow of the plaster but if there is any doubt as to progress it is wise to X ray out of plaster or when the plaster is being changed



FIG 2 A P and verti al projection in a case of posterior dislocation of the shoulder joint

(2) Conditions of Skeletal Trauma that may be Missed Despite the X-ray Examination

(*a*) *Posterior Dislocation of the Shoulder Joint* This is an unusual injury the physical signs of which are often masked by swelling. In particular swelling may mask the flattening of the anterior aspect of the shoulder and prominence of the coracoid process which become apparent as the swelling subsides by which time of course valuable time has been lost in reducing the dislocation with resulting permanent disability.

Radiographically a single antero posterior film of the shoulder may not reveal the dislocation and in all cases of shoulder injury it should be routine practice to take a vertical projection of the joint. This is most conveniently taken with the X-ray tube above the shoulder and a curved cassette in the axilla but if the patient is unable to abduct the shoulder a satisfactory demonstration can be achieved by putting the cassette above the shoulder and the X-ray tube below without moving the elbow from the patient's side. This projection will always demonstrate a posterior dislocation as well as bony relationships in any other form of shoulder injury.

On the routine antero posterior film the features which suggest posterior dislocation (see Fig. 2) are

(i) Internal rotation of the head of the humerus.

(ii) Loss of parallelism between the articular surfaces of the head of the humerus and the glenoid fossa.

(iii) The head of the humerus appearing smaller and its trabecular



FIG. 3 P.A. and lateral projection of the wrist showing fracture of the scaphoid and dislocation of the carpus posterior to the lunate

pattern more clearly defined than usual this is due to the head of the humerus being nearer the film than normally

(*b*) *Trans scapho perilunar Fracture dislocation of the Carpus* The radiographic features of this injury may be difficult to interpret if the surgeon is not familiar with the appearances As in all fracture dislocations time is an essential factor in treatment so it is of importance to recognize the nature of the injury at the first examination

In this injury the scaphoid is fractured the lunate and proximal half of the scaphoid are in normal relationship with the radius and all other carpal bones including the distal half of the scaphoid are dislocated backwards

In most hospitals the routine practice in X raying wrist injuries is to take three projections a postero anterior an oblique and a lateral The bony injury the scaphoid fracture and possibly an associated fracture of the radial styloid will be readily seen on the postero anterior film but it is the lateral film which shows the posterior dislocation of the carpus (see Fig 3)

(3) Head Injuries

Radiographically head injuries can be classified as fractures of the vault of skull fractures of the base of skull and fractures of the facial bones

X ray examinations of the head require besides the co operation of the patient exact and precise positioning of the patient s head positions some of them difficult to achieve and maintain It is useless to send a badly shocked or concussed patient for X ray examination of the head as films obtained under such conditions are unlikely to be of diagnostic value Unless it is the surgeon s intention to deal immediately with a head injury and it is desired to demonstrate the extent of or exclude a depressed fracture of the vault shocked or concussed patients should be treated accordingly before being sent for X ray examination

(*a*) *Fractures of the Vault of the Skull* Of the three radiographic divisions the vault is the simplest to demonstrate only antero posterior and lateral projections being required Fractures of the vault may be seen to be linear or stellate to cross recognizable vascular channels such as the middle meningeal vessels or to involve air sinuses such as the frontal sinus Depression of a fracture will probably not be detected unless stereographic views or a special tangential projection of the fracture site is taken Probably a more certain way of detection is examination with the surgeon s finger during toilet of the scalp

(*b*) *Fractures of the Base of the Skull* A fracture of the base is a diagnosis usually made on clinical grounds Radiographic demon stration of the base of skull is a difficult manoeuvre requiring the full co operation of the patient—co operation usually far beyond the power of any patient on whom a clinical diagnosis of fracture of the base has

been made Further if following a clinical diagnosis of fracture of the base of skull even the most satisfactory films fail to demonstrate a fracture line the patient will still be treated for fracture of the base If for academic or medico legal purposes it is desired to have a permanent record of the fracture the patient can safely be sent for X ray examination the day before his discharge when he is able to co operate fully for such fracture lines persist for many months or even years

(c) *Fractures of the Facial Bones* These injuries comprise fractures of the nasal bones lateral face fractures and depressed fractures of the zygomatic arch upper and lower middle face fractures and fractures of the mandible Their significance is concerned mainly with three factors—they may be concerned with alterations in vision particularly diplopia they may be concerned with dental occlusion and they may have cosmetic effects (see Fig 4)

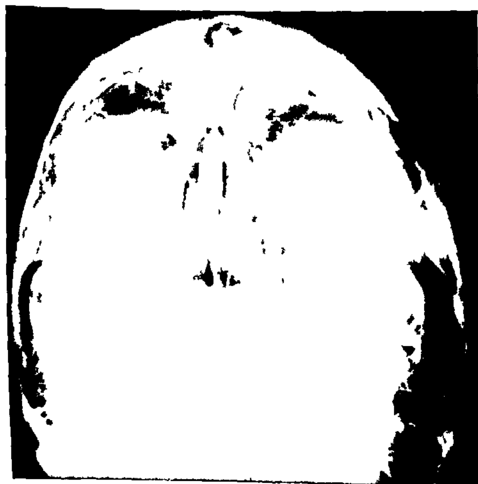


FIG 4 Injury to the face with considerabl soft tissue swelling The film shows fracture of the i fra orbital margin and diastasis of the fronto zygomatic suture and obliteration of the a r space in the antrum due to haemorrhage

Radiographic procedure to demonstrate such fractures is again a precise technique needing considerable co operation by the patient and it cannot be too strongly emphasized that a shocked or concussed patient is unable to co operate and that in such cases when fractures of the facial bones are suspected the patient should not be sent for X ray examination until he has been treated for shock

(4) Foreign Bodies

(*a*) *Swallowed Foreign Bodies* Fish and meat bones not uncommonly become impacted in the pharynx or oesophagus Only a small number of these are sufficiently radio opaque to cast a shadow on a radiograph and then usually only if they lodge above the thoracic inlet Below the thoracic inlet the shadows of ribs lungs and mediastinal structures prevent identification of small shadows In many cases superficial abrasions caused by the swallowing of such small sharp objects create a persistent sensation of discomfort though the foreign body has passed on into the stomach

The old idea of giving a barium swallow to these cases sometimes with pledgets of cotton wool in it has been discarded Such examinations rarely produce useful information The most useful form of radiological examination is (i) a lateral soft tissue film of the neck this may reveal the fish or meat bone impacted in the posterior pharynx or upper oesophagus in these investigations the normal irregular calcification in the thyroid cartilage must not be mistaken for a foreign body (see Fig 5) (ii) Screen examination of the chest if no positive information has been provided by (i) this may reveal unsuspected evidence of inhalation of the foreign body The giving of barium by mouth should be avoided as this usually only makes subsequent examination by oesophagoscopy difficult or useless

More solid foreign bodies such as coins hair grips brooches toy soldiers safety pins etc usually pass down the oesophagus into the stomach Metallic objects such as those mentioned can be demonstrated radiologically and their passage or failure to pass through the alimentary tract observed Once through the pylorus the vast majority pass through the alimentary tract without further delay though occasionally in small children hair grips may become impacted in the duodenal loop By radiographic observation of the passage or delay in such cases a decision as to the rare necessity for surgical intervention can be made

(*b*) *Inhaled Foreign Bodies* Patients who have inhaled a variety of foreign bodies reach most hospitals in the course of any year Metallic objects like pins safety pins paper clips etc present no difficulty in identification or localization Non opaque objects like beads and peanuts the latter being very common in children may create considerable difficulties The routine examination in such cases should

consist of (a) a conventional posterior anterior view of the chest followed by any or all of the following (b) lateral and oblique views of the chest By this stage metallic objects have usually been identified



FIG 5 Impacted swallowed meat bone shown in the soft tissue posterior to the larynx

and localized to a particular bronchus (c) a penetrated antero posterior view of the chest (d) a postero anterior view of the chest taken on expiration (e) screen examination of the chest

The inhalation of a non opaque object such as a peanut may cause collapse of a lobe or segment of a lobe or it may cause a valvular emphysema which is only apparent on expiration by the lobe or segment remaining aerated or blown up when the remainder of the lung becomes de aerated (see Fig 6) Screen examination by an experienced radiologist followed by films in the requisite projection and phase of respiration will usually localize such objects accurately



Fig 6 Chest film shows collapse of the left lower lobe with obstructive emphysema of the left upper lobe due to an inhaled peanut

(c) *Foreign Bodies in Skeleton or Soft Tissues* Usually only metallic foreign bodies can be localized by radiological methods Their relation ship to bony landmarks can be established and by parallax methods their depth can be accurately estimated It is important to carry out these examinations with the limb or part of body in the position in which it will be during surgical approach for the alteration of muscle tension and pull often has a surprising and unexpected effect on tissue planes and the consequent site of the foreign body A foreign body can move a surprising distance along tissue planes or in vascular channels in a matter of a few hours and so it is important that after initial

localization has been carried out a final film of the part should be taken on the way to the operating theatre to confirm that it is in the same site

Non metallic objects such as wood plastic stone etc rarely cast any shadow and their presence or absence cannot be established Occasionally in thin parts such as a finger or a part unobscured by skeletal shadows such as the calf non metallic objects can be identified

(d) *Foreign Bodies in the Eye* Only metallic foreign bodies can be identified in the orbit The surrounding bony cage precludes the possibility of identifying any less dense object The important point to establish is whether the foreign body is in the globe of the eye or in the surrounding soft tissues There are many very accurate methods of exact localization by radiological means of great use to the ophthalmic surgeon Of considerable use to the casualty officer and resident surgeon investigating such cases is the simple technique of taking (i) an occipito frontal projection with a 20 caudal tilt of the tube to show the orbits clear of the petrous temporal bones and (ii) two lateral projections taken without moving the patient s head or the tube one with the patient looking up and one looking down (see Fig 7) From a study



Fig 7 Films showing a foreign body in the eye after a limbal ring has been sewn to the cornea (a) With the patient looking up (b) Looking down

of the movement of the foreign body on these films an immediate estimate of its site within or without the globe can be made It is sometimes argued that foreign bodies in the capsule of Tenon muscle or intra orbital fat show movement nevertheless this method gives a valuable estimate of its site and if need be more accurate localization can be carried out subsequently

(5) Kidney Injuries

A patient arriving in hospital with haematuria following injury to the trunk often presents a difficult surgical problem. Accurate clinical examination is rendered difficult by the marked abdominal rigidity. In such cases the injury may be severe, but it is not uncommon for haematuria to follow quite trivial injuries and it is an established fact that the

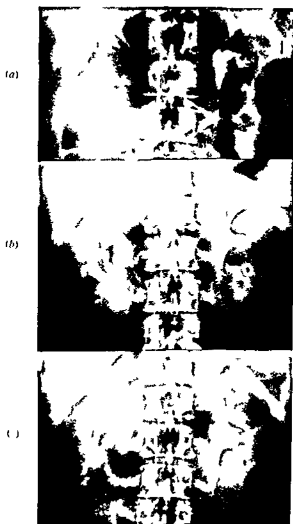


Fig. 8. Excretion Urography in a case of haematuria following injury at football. (a) On the day of the injury. (b) Two weeks later. (c) Four weeks after (b).

(a) Shows meteorism, impaired excretion by right kidney and absence of its middle calyx.
(b) Shows intra capsular tear with a pool of contrast medium within the renal substance.
(c) Shows complete repair and normal function of the injured kidney.

extent of the haematuria bears little relationship to the severity of the kidney damage

There is no place for retrograde pyelography in these cases The risk of causing further haemorrhage or introducing infection are too great, especially in an era when the emphasis is on the conservative treatment of kidney injuries

The surgeon requires to know (*a*) the extent of the kidney damage (*b*) that the other kidney is present and functioning normally and (*c*) the presence of any associated injuries All this information is readily obtainable by means of excretion (intravenous) urography which can be safely undertaken once the period of initial shock has been overcome

The preliminary films may show the following features in cases of kidney trauma (*a*) a slight protective scoliosis concave to the affected side (*b*) obliteration of the psoas shadow (*c*) loss of the kidney outline (*d*) fullness of the affected flank (*e*) injury to the bony skeleton usually the twelfth rib or upper lumbar transverse processes (*f*) meteorism of the bowel often very marked frequently localized over the injured kidney

On excretion urography the following features may be seen (*a*) failure of visualization of a calyx (*b*) irregularity of one or more calyces (*c*) calyceal rupture (intra capsular) as evidenced by a pool of contrast medium contained within the kidney outline (*d*) intra capsular tear so extensive as to cause complete disorganization of the kidney showing as pools of contrast medium without recognizable calyceal structure (*e*) extra capsular rupture with contrast medium tracking outside the kidney (*f*) failure to excrete or diminished excretion by the affected kidney it is important to realize that a kidney which is functionless following injury can recover completely (*g*) displacement of the kidney or displacement of the ureter by a retro peritoneal haematoma

By this investigation the presence and condition of the unaffected kidney are shown Similarly the presence of previously unsuspected renal pathology may be shown for instance a hydronephrotic kidney ruptures and bleeds more easily than a normal kidney And finally when conservative treatment is being employed the progress of the injury and its repair can be studied by serial urographic studies (see Fig 8)

(6) Abdominal Emergencies

For the radiological investigation of intestinal emergencies only high quality films taken with high output machines in the X ray Department are of any diagnostic value Films taken with a mobile unit are rarely of the required quality and attempts to interpret them are more likely to be misleading than helpful

(*a*) *Intussusception* Intussusception in the adult is usually chronic and is usually demonstrated during barium enema investigation of

alteration in bowel habit or of intermittent attacks of colicky abdominal pain

Intussusception in childhood is commonly acute in onset and the clinical picture is often sufficiently clear cut to require no radiological investigation Occasionally however there may be no palpable tumour and the surgeon may be uncertain of the diagnosis especially as many of the clinical features of this condition may be simulated by an acute gastro enteritis The present low mortality in intussusception is only maintained by early surgical treatment which is dependent on early diagnosis

In cases of doubt plain radiography of the abdomen can help The radiological appearances of intussusception may be

(1) Direct visualization of the intussusception the caput showing as a rounded convex shadow projecting into gas in the colon distal to it Gas in the lumen in the intussusception may be seen as a linear shadow proximal to this (see Fig 9)



Fig 9 Plain radiograph of an abdomen in a case of intussusception in an infant showing the caput of the intussusception outlined against gas in the colon distal to it

(ii) A soft tissue mass in the right lower quadrant of the abdomen with complete absence of intestinal gas from this quadrant and displacement of gaseously distended bowel to other segments of the abdomen

(iii) The radiological picture of intestinal obstruction without any indication of the cause

A barium enema should rarely be necessary as a diagnostic measure

The practice of therapeutic reduction of intussusception by barium enema which has been widely used for many years in Scandinavia is gaining popularity in this country There are certainly no grounds for a change from the surgical technique which has long been accepted in this country unless equally certain and satisfactory results can be obtained by this non operative procedure If therefore it is to be carried out it should only be done by an experienced radiologist with the consent of and in the presence of the surgeon who must accept the responsibility of operating on the child if this procedure proves unsuccessful The barium enema technique is as follows

(i) Preliminary plain films of the abdomen are taken in order to assess the degree of intestinal obstruction and if possible the type of intussusception

(ii) Barium enema is then administered under low pressure (i e a column of 12–18 in) under fluoroscopic control in order to demonstrate and localize the caput of the intussusception Films are taken at this stage (see Fig 10)

The occlusion of the child s anus by a firm cotton wool pad or by a metal or plastic obturator and the constant control of this by a nurse or radiographer is of great importance

(iii) The hydrostatic pressure is then gradually increased by increasing the height of the column of barium up to 3 or 4 ft In exceptional cases it may be necessary to raise it to 5 ft but usually 3 ft is enough Reduction is controlled by fluoroscopic observation palpation and manipulation are not performed reduction being entirely by hydrostatic pressure Reduction is considered to be complete when (*a*) complete filling of the caecum is observed and (*b*) there is flooding of the barium back into the ileum Further films are taken at this point

(iv) Whether or not reduction is successful the barium is drained off and post evacuation films taken The whole series of films can then be studied for full evaluation of the state of affairs

(v) If there is any doubt as to the success of the reduction the whole procedure may be repeated

(vi) Post barium enema care and observation are of course essential

(*b*) *Perforation of a Hollow Viscus* Perforation of a gastric or duodenal ulcer usually allows an escape of sufficient gas into the peritoneal cavity to allow its demonstration provided a horizontal

X ray beam is used If the patient can stand the free gas will be demonstrated under the diaphragm but if he is unfit to stand for the examination a horizontal beam can still be used with him lying in the lateral



FIG 10 Barium enema in an infant showing the caput of the intussusception projecting into the barium column at the hepatic flexure

decubitus position or even a lateral film of the abdomen with the patient supine

Perforation of an inflamed viscus such as the appendix or a diverticulitis of the colon rarely allows the escape of intestinal gas Plain radiography of the abdomen in such cases will show the appearances

of an inflammatory ileus It is not recommended that radiological aid should be a routine diagnostic measure in such cases for the diagnosis will be apparent from a proper clinical examination Nevertheless when radiological aid is invoked in the elucidation of difficult or suspected cases of abdominal emergency this pattern will be sometimes encountered and it is essential that those faced with the need to interpret the investigation should be familiar with its appearances which are described on page 22 under post operative ileus

(c) *Intestinal Obstruction* The radiological appearances of intestinal obstruction are abnormal gaseous distension of and stasis in gut proximal to the obstructing lesion and absence of gas from gut distal to the lesion Stasis is shown by separation of gas and fluid to form fluid levels in the distended loops of bowel with the patient in the erect position or when some other means of using a horizontal X ray beam is employed It must however be realized that fluid levels alone are not an indication of obstruction they merely mean that the contents of a particular loop of gut were static at the moment of exposure

The usual practice is to take an antero posterior film of the abdomen with the patient supine and a postero anterior film with him erect If the patient is unfit to stand for the second film it is sufficient to take only the former for it is usually possible to make a complete analysis of all the bowel shadows present from the supine film



Fig 11 Supine and erect films of the abdomen of a three day-old infant with signs of obstruction showing distension of the ileum stasis in the ileum complete absence of gas from the large bowel and peritoneal layering due to peritoneal exudate At operation atresia of the terminal ileum was found

Probably the most valuable field for the application of this investigation is in cases of suspected neonatal obstruction. Swallowed air has usually reached the lower colon and rectum by 12 hr after birth and invariably by 24 hr so that after that time a useful opinion can be given regarding the presence or not of an obstructing lesion (see Fig. 11).

In cases of doubt surgical practice is to keep a patient under observation and to carry out clinical examination from time to time. The same procedure can and should be applied to radiological examinations, and if after a period of hours there still remains doubt further radiological examination may be of diagnostic value. This applies



Fig. 12 Supine film of the abdomen in a case of volvulus of the sigmoid colon showing great distension of the single loop of colon

particularly again to the field of neonatal problems and in suspected obstruction in childhood

Certain forms of obstruction have characteristic appearances which should always be borne in mind such as meconium ileus in the neonatal period and volvulus in adults In the former in addition to the usual radiological signs of mechanical intestinal obstruction there can often also be identified in the lower right quadrant of the abdomen the speckled densities of retained meconium

In volvulus the single loop of distended bowel may be seen crossing and occupying the entire abdomen in these cases the distension of the twisted loop of bowel often reaches very considerable proportions (see Fig 12)

CHAPTER 2

POST-OPERATIVE CONDITIONS

(1) Post Thoracotomy Observation

MANY thoracic operations are of a highly specialized and intricate nature, and it is beyond the scope of this book to discuss them Never theless a trans thoracic approach to abdominal procedures such as gastrectomy or nephrectomy are daily events in most general hospitals as are also intra thoracic surgery such as exploration of the oesophagus or pericardium ligation of patent ductus arteriosus mitral valvotomy etc

In all procedures when the thorax has been opened post operative care and observation are of the greatest importance An essential aid to clinical observation is chest radiography This is carried out in the ward with a mobile X ray unit In the immediate post operative phase many patients are restless and due to their rapid shallow respiration are unable to co operate well for the X ray examination Even so provided attention is paid to detail using fast film high speed intensi fying screens and possibly a stationary grid and reducing the anode film distance an experienced radiographer with the help of a nurse will produce a well penetrated antero posterior film of the patient sitting up or semi recumbent which will be of diagnostic value and of great clinical help

Such a film will show —

(*a*) the presence or absence of a pneumothorax If pneumothorax is demonstrated its extent and any unacceptable complication such as mediastinal shift can be assessed

(*b*) the presence or absence of pleural effusion

(*c*) pulmonary collapse or consolidation

(*d*) the site and relationship to fluid of any drainage tube that has been left in the thorax

By means of subsequent follow up films the course of any feature noted and its response to treatment can be judged and controlled

(2) Post-operative Ileus

This condition may be either an inhibition ileus or an inflammatory ileus but in practice the two may co exist and it is often not possible to separate the one clearly from the other

The problem that sometimes faces the surgeon is when on the fifth or sixth post operative day the patient begins to vomit and his abdomen becomes progressively distended to decide whether this is an ileus or a

supervening mechanical obstruction requiring further surgery The diagnosis may be further confused by the presence of audible bowel sounds and the passage of flatus



FIG 13 Plain film of the abdomen showing an inflammatory ileus in a 12 year old boy after drainage for a perforated appendix

Radiological examination of the abdomen in these cases can often help It must again be emphasized however that films taken with a ward mobile unit and under ward conditions are rarely of sufficient

quality to be helpful and may even be misleading. If this examination is to be of any significance the films must be of the very highest quality such as can only be produced using high ouptut apparatus and a Potter Bucky grid in the X ray department. The surgeon in charge therefore must decide whether the information that may be forthcoming from such an investigation is sufficiently in the interests of the patient and is likely to influence the course of treatment to such an extent as to justify the patient's journey to the X ray department.

Preferably two films of the abdomen should be taken one with the patient supine and one erect but if he is unable to stand valuable diagnostic evidence can be obtained from the supine film.

In an ileus gas is usually present to a varying degree through all the bowel large and small. If the ileus is localized for example in relation to a localizing pelvic abscess then the loops of gut both large and small in that segment are abnormally distended and there may be local peritoneal layering. If the ileus is generalized as in a true inhibition ileus then the abnormal distension of multiple loops of small and large bowel occupies the whole abdomen. If the condition is a generalized inflammatory ileus associated with a generalized peritonitis then in addition to the widespread abnormal distension there will also be diffuse peritoneal layering and loss of the pro peritoneal line. The term peritoneal layering is used to denote that loops of gut are separated by a soft tissue shadow that is both wider and denser than normal due to peritoneal oedema or exudate (see Fig 13).

It must be remembered that some degree of bowel distension occurs as a result of any laparotomy in which bowel is handled. The interpretation of these investigations is no simple matter and the differentiation on X ray films between simple post operative distension post operative ileus and a mechanical obstruction is often a problem requiring great experience and it is wise in these cases always to have a radiological opinion.

(3) Swabs Left in the Abdomen

Despite careful precautions routine swab counts and established techniques there still arise unfortunate cases of swabs left in the abdomen and there still comes the occasion in the theatre when despite counts and re counts a swab remains missing.

Swabs unfortunately are not opaque to X rays and cast no shadows.

Some commercial firms have produced swabs containing a single impregnated thread which will cast a shadow and their use for all abdominal operations is becoming increasingly popular.

Alternatively some surgeons have devised the practice of always clipping a Michel's clip to a swab before introducing it to the abdominal cavity. The metal clip of course is easily demonstrable radiologically and in cases of doubt an X ray mobile unit can be brought to the

theatre for a film of the abdomen to be taken before the patient leaves

(4) Sub-phrenic Abscess

The clinical diagnosis of sub phrenic abscess is often difficult to make Radiological investigation has a very definite role to play in establishing a diagnosis Similarly in suspected cases of sub phrenic abscess if all the radiological criteria are absent the surgeon can feel reasonably certain that the possibility is unlikely though it may never be said to be positively excluded The radiological features that may be found in this condition consist of changes in the diaphragm changes above the diaphragm and changes below the diaphragm

A full examination should consist of (*a*) screen examination of the diaphragm (*b*) postero anterior and lateral films of the chest (*c*) a penetrated antero posterior film of the chest, (*d*) a postero anterior film of the upper abdomen with the patient erect

The changes in the diaphragm consist of

(*a*) Diminution or absence of movement of the diaphragm on the affected side

(*b*) Elevation of the diaphragm on the affected side

Elevation of the dome may be either localized or generalized It is however a difficult sign to evaluate the right dome of the diaphragm is normally an inch higher than the left in an adult and any variations in the normal contours may be produced either when a patient is unable to stand for the examination or unable to achieve normal respiratory excursion (see Fig 14)



FIG 14 The diaphragm in a case of sub phrenic abscess The right dome is elevated and there are inflammatory changes in lung tissue overlying the diaphragm

(*c*) Loss of definition of the outline of the affected dome of the diaphragm (see Fig 15) This too is a difficult sign to evaluate in a patient who is perhaps unable to co operate fully but may be of

significance when there is asymmetry between the two domes of the diaphragm and there are other confirmatory radiological signs



FIG 15 Loss of definition of the right dome of the diaphragm in a case of sub phrenic abscess

The changes above the diaphragm consist of

(*a*) Pleural effusion This is a common event in sub phrenic abscess A small effusion obliterates the costo phrenic angle while a larger one obscures the outline of the diaphragm and rises laterally along the axillary border *Elevation of the dome of the diaphragm may render the* appearances difficult to interpret but the penetrated film of the chest will usually establish the point

(*b*) Inflammatory lung changes These are usually localized being due to direct spread of the inflammatory process across the diaphragm and have the appearance of patchy or lobular consolidation in a lung segment in direct contact with the diaphragm (see Fig 14)

(*c*) Pulmonary collapse This is not a common finding but when it occurs it is invariably the lower lobe of a lung and if occurring alongside some of the other changes described is confirmatory evidence

(*d*) Suppurative lung changes Rarely sub phrenic abscess may give rise to an empyema or lung abscess

The changes below the diaphragm consist of —

(a) An abnormal gas collection below the diaphragm Gas following laparotomy is usually demonstrable for 5–7 days following operation but may persist for up to 10 days After that time extra intestinal gas below the diaphragm must be regarded as abnormal However, the presence of gas in sub phrenic abscess is a relatively rare finding being present in fewer than a quarter of all cases

(b) An extra intestinal fluid level This finding requires the presence of both gas and fluid and really is a corollary to (a) that is to say that when gas is demonstrated if the radiological examination is continued to that end a fluid level will almost invariably be found

(5) Pulmonary Infarction

In many cases of pulmonary infarction occurring as a post operative complication the episode and the clinical symptoms and signs leave no doubt as to the diagnosis However there are cases in which the symptoms and signs are less clear cut in which it is essential to establish a definite clinical diagnosis before instituting anti coagulant therapy

Radiological aid can usually be of help in these cases

The radiological signs of pulmonary infarction on a chest X ray film (see Fig 16) consist of —

(a) *Diaphragmatic Changes* The most common alteration is elevation of the dome of the diaphragm on the affected side less commonly peaking of the diaphragm will be detectable in which at one point the affected dome is drawn up to a sharp point

(b) *Pleural Changes* A small localized effusion is the commonest change Large effusions do occur following pulmonary infarction but this is more likely to happen when it is a complication of cardiac failure Usually it merely shows as an obliteration of the costo-phrenic angle This pleural oedema or effusion actually occurs in the pleura adjacent to the segment of affected lung

(c) *Lung Changes* In many cases there is no detectable lung [illegible] while in some few massive consolidation of a whole lobe may [illegible] When there is abnormal shadowing the commonest finding [illegible] rounded shadow in the periphery of the lung with clearly defined [illegible] it always has a pleural surface though this may not be [illegible] unless oblique projections are taken

If the chest film is taken within the first 24 hr after the [illegible] episode there may be no radiological abnormality *If the film is* first class quality—this may not be achieved with ill patients it may be possible to detect a segment of relative ischaemia in the lung [illegible] even to see the abrupt *end of a large pulmonary vessel* [illegible] period of ischaemia following the [illegible] vessels are attempting to [illegible]

onset of true infarction A further film 24 hr later will often show this segment of lung now to consist of solid infarct



FIG 16 Portable chest film for a case of pulmonary infarct There is elevation of the right dome of the diaphragm a small pleural effusion in the costo phrenic angle and considerable lung consolidation adjacent to the pleural effusion

Of the changes described none alone is diagnostic of pulmonary infarction Two or more occurring together alongside the clinical picture will usually establish the diagnosis

CHAPTER 3

THE MOUTH, NOSE AND NECK

(I) Swellings of the Lower Jaw

SWELLINGS of the lower jaw other than those due to acute inflammatory disease often present difficulties in diagnosis Low grade chronic inflammatory conditions degenerative changes dental tumours and bone tumours may all present with a chronic relatively painless swelling with or without alterations in occlusion X ray examination is of the greatest value in helping to establish a diagnosis and as an aid to the planning of treatment

Chronic inflammation may rise from a dental apical abscess this may either be localized or give rise to a chronic spreading osteomyelitis If localized the X ray appearance is of an area of diminished bone density possibly with entire loss of visible bony trabeculae in relationship to a tooth root The affected area may have a well defined edge or be more diffuse and indistinctly delimited from the surrounding bone The lamina dura may also be affected showing that in addition to the mandible the tooth is also involved If the condition is not localized usually there is a diffuse change in the bony texture of the affected ramus of the mandible the whole having a coarser and more sclerotic appearance then normal In long standing cases the mandible may be thickened by the apposition and incorporation into its structure of new sub periosteal bone along its lower border Occasionally though the condition may be of some weeks or even months standing when the patient is first examined radiological examination will show new sub periosteal bone along its lower border which has not yet been incorporated into the structure of the mandible—a periosteal reaction showing as thin laminae of new bone running parallel to the cortex This indicates an inflammatory process it may be seen in adults or children and is not always associated with dental infection This appearance associated with bilateral swelling of the jaw is sometimes encountered early in infancy This is a manifestation of infantile cortical hyperostosis and is usually co existent with similar involvement of one or more other bones e g the clavicle or a long bone of an extremity The onset is always within the first six months of life and the children affected are markedly irritable and present with fever and soft tissue swellings over the involved bones The cause is not known but is thought to be infective probably a virus infection the bony lesions being very similar though not so gross as may occur in small pox a known virus infection The

condition is self limiting runs a definite course and the lesions involute without suppuration within three to twelve months

The degenerative conditions which may cause chronic swelling of the jaw are fibrous dysplasia and Paget s disease In the case of the former it may be the sole manifestation of the condition or it may be part of a polyostotic fibrous dysplasia In either case it tends to be slowly pro gressive with long quiescent phases In the case of Paget s disease the prognosis is similar—slow progression Both these conditions produce an alteration in the trabecular pattern of the mandible Fibrous dys plasia produces a pattern in which the normal trabeculae disappear and are replaced by bone of increased density but having no true trabecular network—only a ground glass appearance usually with some expansion of the affected part of bone The edges of the patho logical process are ill defined, merging imperceptibly with normal bone Involvement of the mandible by Paget s disease is rarer and when it occurs affects usually only the elderly whereas fibrous dysplasia may occur in any age group in adult life or even adolescence In Paget s disease the normal trabecular bone is replaced by coarser thicker trabeculae with wide inter trabecular spaces and there is expansion of the affected part of bone

Though the differential diagnosis by radiological methods of the larger dental tumours and bone tumours affecting the mandible as a pre operative measure is largely an academic exercise it is not entirely academic for prognosis is mainly governed by correct diagnosis The common tumours to cause swelling are dental cyst adamantinoma and ossifying fibroma osteoclastoma plasmocytoma and sarcoma also occur Small dental cysts usually cause no difficulty in diagnosis and some cases of ossifying fibroma have characteristic appearances but in either case the differential diagnosis from adamantinoma may be impossible Dental cysts usually appear as well defined areas of trans lucency within the mandible, possibly in close relationship to or containing a tooth element possibly causing bony expansion and usually containing no septa Ossifying fibromata are usually well defined slow growing tumours with a quite definite bony edge or capsule They often cause very considerable bony expansion Some times they have one or two large septa crossing an apparently structure less centre sometimes the centre of the tumour is occupied by an amorphous mass of varying densities It is perhaps incorrect to differentiate between fibrous dysplasia and ossifying fibroma for histologically they are the same Yet clinically and radiologically ossifying fibroma in the mandible appears to be a distinct entity a tumour neoplastic in origin while the mandibular manifestations of polyostotic fibrous dysplasia appear more to be a local display of a generalized error in bone development

Adamantinomata may simulate either of the appearances described

for dental cysts or ossifying fibromata Characteristically an adamantinoma produces a multi locular cystic area in the mandible causing some expansion and having well defined edges (see Fig 17) However, not all examples produce this appearance some have no septa or loculi some have ill defined infiltrative edges some cause no expansion some cause definite expansion but also show definite destruction of their outer cortical walls



Fig 17 Adamantinoma in the right side of the mandible affecting the horizontal and superior rami The cystic spaces within the tumour are well demonstrated

The foregoing description shows that radiology has definite limitations in the diagnosis of these conditions Diagnosis is definitely a function of the expert histologist in this field Yet radiology has a definite role to play The treatment of these lesions is surgical and careful planning is required both in deciding the extent of bone to be excised and in arranging for subsequent prostheses Careful radiological examination will reveal the geography of jaw tumours their site and limits and their effects on dental occlusion thus aiding radical surgical treatment and subsequent plastic repair

In this field one last condition must be mentioned Buccal carcinoma even though apparently superficial and without evidence of glandular involvement not uncommonly invades the underlying alveolar margin Radiological examination will often reveal changes in underlying bone —an ill defined irregular osteoporosis affecting the alveolar margin

under the buccal neoplasm (see Fig 18) This is not necessarily entirely due to neoplastic invasion of the bone for the site especially if there is superficial ulceration often becomes secondarily infected and the *bony changes may be mainly inflammatory Nevertheless the radio* logical examination showing such changes makes it clear that there is



FIG 18 Invasion of the right horizontal ramus of the mandible by buccal carcinoma The alveolar margin has been d stroyed and the edge of the invading process is ill defined

pathological involvement of bone and warns of the necessity for wide excision

(2) Salivary Glands

Recurrent or persistent swelling of a salivary gland often produces a difficult diagnostic problem In the submandibular gland the cause is usually a calculus and less frequently a benign tumour In the parotid gland calculi are rare and the more common causes are (*a*) non obstructive pyogenic parotitis (*b*) duct stenosis or (*c*) parotitis secon dary to duct stenosis Occasionally benign or malignant tumours occur

Radiological investigation consists of plain X ray examination and sialography

In the sub mandibular gland plain X ray examination will often reveal the calculus and there is no need to proceed further In the case

of the parotid gland in order to gain useful information it is usually necessary to carry out sialography (see Fig 19)



FIG 19 Normal parotid sialogram

The technique is to cannulate the duct and to inject an opaque medium The simplest cannula to use is a lachrymal duct cannula In cases of duct stenosis it is usually necessary to dilate the papilla with lachrymal duct dilators An iodized oil (Neohydriol) is the opaque medium of choice as the water soluble media tend to pour back round the cannula Injection should be carried to the point where there is definite discomfort in the gland—usually ¾–1 ml is required for the sub-mandibular gland and at least 2 ml for the parotid gland For complete examination it is desirable to achieve acinar filling in the past this has been wrongly termed sialo acinar reflux and compared to pyelo renal back flow it is not however a backflow phenomenon but merely complete filling of the duct acinar system

Non obstructive pyogenic parotitis which may be due to a variety of organisms including streptococcus viridans and the pneumococcus manifests itself as a series of sacculae of varying size studded along all the subsidiary ducts through the substance of the gland It has been likened to the appearance of saccular bronchiectasis and the term sialectasis or sialangiectasis coined to denote the condition (see Fig 20)

In either gland stenosis may be papillary or buccal but wherever the site of the stenosis there is always dilatation of the duct proximal to

Fig 20 Parotid sialogram showing diffuse sialectasis due to non obstructive pyogenic parotitis



Fig 21 Submandibular sialogram showing papillary duct stenosis with dilatation of the main duct and of its main branches within the gland There is also a buccal stenosis of the duct

the obstruction If recurrent pyogenic infection occurs secondary to duct stenosis in addition to the dilated main duct beading is seen along the subsidiary ducts with probably saccule formation along and at the ends of some of them (see Fig 21) Tumours such as tuberculous adenopathy of lymphoid tissue or mixed parotid tumours show as filling defects within the gland substance The former are usually circumscribed and clearly defined and the latter in their early stages not uncommonly produce similar appearances

(3) The Post Nasal Space

Clinical examination of the post nasal space may be difficult in children it may be impossible And even if the part can be examined by indirect vision it is often difficult or impossible to decide the extent and limits of a pathological process



Fig 22 A lateral film of the naso pharynx showing enlargement of the adenoid tissue causing narrowing of the post nasal air passage

By radiological methods it is possible to obtain useful demonstrations of this part and so add to the diagnostic signs in assessing a clinical problem A properly exposed lateral film of the post nasal space shows



FIG 23 Sub mento vertical view of the base of skull showing a soft tissu mass projecting into the pharyngeal air space from the lateral wall This proved to be lympho epithelioma No bone destruction in the base of skull i shown

the hard palate and soft palate and the post nasal air passage bounded posteriorly by the soft tissues lying in front of the cervical spine This latter soft tissue shadow lies close to the spine running parallel to it Sometimes the soft tissue shadow of the lobe of one or both ears is projected into the air space of the post nasal air passage in this lateral film and must not be interpreted as an abnormality

The soft tissue shadow of adenoid tissue in children can be seen before

it undergoes involution projecting from the posterior naso pharyngeal wall into the air passage In those cases where surgical removal is contemplated the size of the adenoid tissue and to what extent it is



FIG 24 Lateral film of the naso pharynx showing a large round choanal polyp lying above the soft palate

occluding the post nasal air passage—an important clinical feature—can be demonstrated by this means (see Fig 22)

Similarly soft tissue tumours may be demonstrated in this site in the adult due to abnormal lymphoid hyperplasia or due to actual neo plasm such as lympho epithelioma carcinoma or reticulo sarcoma Where such a condition is suspected either on clinical grounds or from inspection of the lateral film a further useful film is the submento vertical projection of the base of the skull The air column of the

naso pharynx can be identified on this film and any soft tissue mass projecting into it can be localized (see Fig 23) At the same time it can be noted whether or not there is actual invasion and destruction of bone in the base of the skull

A further condition that can be diagnosed in the lateral film of the naso pharynx is the presence of choanal polypi These attached by a stalk to their site of origin inside one of the para nasal sinuses project into the air space lying usually above the soft palate (see Fig 24)

(4) The Pharynx and Upper Oesophagus

In a lateral film of the neck the pharynx is seen as an air space behind the buccal cavity and below the soft palate It is bounded posteriorly by the soft tissue lying in front of the cervical spine and anteriorly by the base of the tongue showing as a smooth curved soft tissue shadow At its lower end it is bounded in front by the laryngeal structures, these are discussed in the next section Below the larynx the air column of the trachea is shown there is rarely air in the oesophagus which commences at the level of the upper part of the larynx At the base of *the neck at the level of the thoracic inlet the air shadows of the lung* apices may sometimes be seen The pre vertebral soft tissue shadow narrow in the naso pharynx increases in depth as it passes downwards until behind the thyroid and cricoid cartilages and upper trachea it is about 1 cm in width or approximately the same width as the vertebral bodies lying behind it

Various conditions may be demonstrated in the pharynx and upper oesophagus by X ray examination

Irregularity of the soft tissue contour of the base of the tongue may be due to syphilitic ulcer or to neoplasm This is best examined by direct or indirect vision but frequently X ray examination can give some indication of the extent of the lesion and of its relationship to other structures

Retropharyngeal abscess will always produce increase in the depth of the pre vertebral soft tissue shadow and this examination will not only *confirm a clinical diagnosis but also show the extent of the condition* Retropharyngeal abscess usually gravitates downwards and may even produce a mediastinitis A lateral film of the neck will show its extension towards the thoracic inlet This condition if due to a perforating injury to the pharyngeal wall as is usually the case will often contain air or gas which shows as a gas shadow above a fluid level in the swollen soft tissues (see Fig 25)

Generalized increase in the depth of the pre vertebral soft tissue shadow may also be due to a tuberculous abscess tracking from tuberculous caries of the cervical spine detailed examination of the bony structures of the neck must therefore always be made Long standing retropharyngeal abscess may also in rare cases affect the cervical

spine by contiguity producing an osteitis or purulent involvement of an intervertebral disc and the adjacent vertebrae In this latter case however there is no doubt on clinical grounds as to the nature of the condition and there is unlikely to be any confusion with tuberculosis

The clinical history of a large pharyngeal pouch is usually classical Radiological examination by barium swallow serves to confirm the diagnosis and show the size of the pouch and its pressure effects This condition is now thought by some authorities to be due to a constricting



(a) (b)

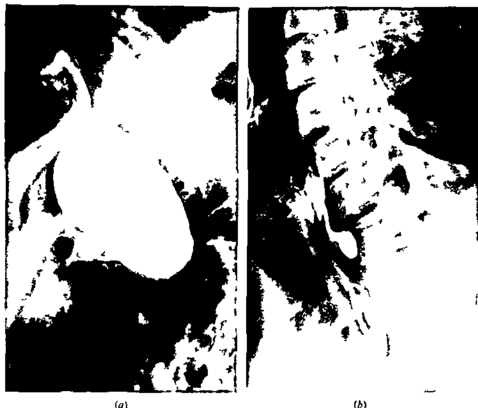
FIG 5 (a) A retro pharyngeal abscess showing as an increase in the pre vertebral soft tissue space There is a marked cervical kyphosis (b) A retro pharyngeal abscess which has cavitated showing a fluid level below a gas containing space

mechanism in the upper oesophagus a normal mechanism which fails to relax thereby increasing pressure in the segment immediately above it—an achalasia of the upper oesophagus The pouch thus fills first and flow down the oesophagus does not take place until it is full and overflow occurs In the first instance it lies behind the oesophagus but as it enlarges it may occasionally come to lie to one side possibly deviating the adjacent oesophagus to the other side As it becomes bigger it becomes dependent and its neck remains at its upper border All these features including the narrow segment below the neck of the pouch can be observed during barium swallow examination and demonstrated by the taking of spot films during the examination (see Fig 26)

The so called classical symptoms of pharyngeal pouch may not be evident during the early stages of its development and there may be no more than a mild or transient and intermittent upper oesophageal dysphagia Such mild cases of dysphagia especially if persistent or recurrent should therefore always be examined by this method

Barium swallow examination of upper oesophageal dysphagia may sometimes bring to light other causes For example gross osteophytosis

of the cervical spine may produce such indentation and distortion of the adjacent oesophagus as to cause discomfort or pain on swallowing In routine radiological work anterior osteophytes protruding round cervical intervertebral discs are often found projecting into the posterior wall of the oesophagus and the vast majority of these produce no



(a) (b)

Fig 26 (a) A large pharyngeal pouch filled with barium It is shown to be dependent and to project into the thora ic inlet (b) A small pharyngeal pouch filled with barium It is shown to lie in the post-cricoid space and to be dependent its orifice lying at the top The relative narrowing of the oesophagus immediately below the orifice is well shown

symptoms There can be no doubt however that sometimes they are associated with symptoms It is not always the extensive osteophytosis involving several discs that causes the condition and sometimes it may be associated with prominent osteophytes round only one disc In view of the fact that the condition can be symptomless it is important not to incriminate this finding as the cause until all other possibilities have been excluded

Another cause of upper oesophageal dysphagia which may be found at barium swallow examination is the presence of a post cricoid or oesophageal web (see Fig 27) The etiology of this condition often associated with an iron deficiency (hypochromic) anaemia is not under stood The web may be small or almost complete it may be transient

or persistent it may project anteriorly, posteriorly or laterally into the oesophagus and it may be found during a search for a cause of dysphagia or it may be found in a symptomless patient being investigated for a hypochromic anaemia Sometimes when the condition has been



FIG 27 Barium swallow showing an oesophageal web just anterior to the intervertebral space between C V 5–6

demonstrated radiologically subsequent oesophagoscopy fails to find the web yet when these cases are re X rayed the web is no longer present and it seems likely that the web has been broken down by the passage of the oesophagoscope Certainly when the oesophagoscopist sees the web and passes his instrument beyond it it then disappears both from subsequent review of the area with the instrument and at radiological examination If the web has been producing symptoms

breaking it down by this direct approach invariably relieves the symptoms It has been believed by some authorities that this condition is pre malignant and can be the precursor of post cricoid carcinoma



Fig 28 A post-cricoid carcinoma outlined by barium Its extent is reasonably well shown in this film

Post cricoid carcinoma can be demonstrated and diagnosed radiologically on the lateral film of the neck by the localized increase in the depth of the soft tissue pre vertebral shadow behind the trachea at or just distal to the level of the cricoid cartilage Barium examination will show its extent (see Fig 28)

(5) The Larynx

The main application of radiological methods as an aid to diagnosis in this field is in demonstration of the extent of neoplasm Carcinoma of the larynx may be an intrinsic tumour affecting the vocal cord area or an extrinsic tumour which may be supra glottic or sub glottic Supra glottic tumours and tumours of the vocal cords can be viewed by



FIG 29 A lateral film of the neck showing a carcinoma of the vallecula projecting as a soft tissue mass into the air space of the pharynx Its extent and margins are well shown

endoscopy Even so radiographic demonstration by means of tomography will often add valuable information as to the size and extent of the growth before operative or radio therapeutic treatment is undertaken During the course of radiotherapy this method will also demonstrate the response to treatment and the regression of the mass so contributing to the control of treatment

In the case of sub glottic tumours which cannot be viewed by endoscopy radiographic demonstration by means of tomography is the only satisfactory method of completing clinical examination In all tumours intrinsic supra glottic or sub glottic this method will show the lowermost limits of the growth

Radiographic investigation consists of (*a*) a conventional lateral film

of the neck (see Fig 29) This shows the vallecula the epiglottis the thyroid cartilage and the air column of the trachea (*b*) tomography in the frontal (AP) projection this is carried out in ½ cm sections

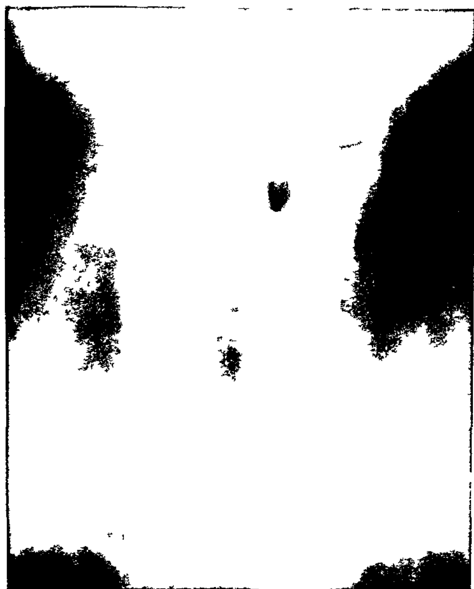


FIG 30 An A P tomogram of the larynx taken during phonation showing a supra glottic carcinoma. Its lower extent is well shown, a feature which could not be determined at clinical examination.

with the patient phonating thus bringing the vocal cords together and providing good visualization by the contrast with surrounding air (see Fig 30)

(6) The Neck

(*a*) *Branchial Fistula* The external orifice of a branchial fistula is usually in the lower third of the neck near the outer border of the sternomastoid Some have an internal orifice, but most are blind fistulae If surgical excision is contemplated radiological demonstration of the size direction and extent of the fistulous track is desirable This is achieved by injecting the sinus with an opaque medium—either lipiodol or one of the modern water soluble media such as hypaque can be used When injection has been made slowly to the extent of



Fig 31 Injection of opaque medium into a branchial fistula showing the extent of its tract downwards and also its internal orifice

producing regurgitation from the orifice the skin surface is carefully cleaned and films in two planes postero anterior and lateral are taken (see Fig 31)

(*b*) *Cervical Adenopathy* Radiological examination has little or no part to play in the demonstration of cervical adenopathy or in the differential diagnosis of cervical glands It is however worth recording that the only cause of calcification in cervical glands is tuberculosis Tuberculous glands undergoing fibrosis necrosis and resolution take 18 months to 2 years to calcify Thus the demonstration of calcification in cervical glands indicates involuting tuberculous infection of 2 or more years standing This may sometimes be a useful point in differential diagnosis

(*c*) *Cervical Rib* Brachial plexus and arm neuropathies are more commonly due to cervical spondylosis or other causes than to cervical ribs Nevertheless in the full investigation of such cases the possibility of cervical rib must always be considered and its exclusion is sometimes a useful step Antero-posterior radiographic examination of the cervical spine will demonstrate or exclude the presence of a cervical rib A satisfactory demonstration will include the whole of the cervical spine so that each cervical vertebra can be identified and counted This can be achieved by the moving mouth technique—a relatively long X ray exposure is made and the patient is instructed to move his lower jaw up and down during the exposure this has the effect of blurring out the shadow of the mandible and so all the cervical vertebrae can be identified If this manoeuvre is not successful it is usually accurate to say that there is a definite difference between cervical transverse processes and thoracic transverse processes the thoracic transverse processes are generally slightly longer than their cervical counterpart and also have a slight upward tilt whereas the cervical transverse processes have a slight downward tilt The segment of origin of a rib can thus be determined with reasonable accuracy

(7) Thyroid

Where surgery of the thyroid is being considered it is wise to adopt the practice of X raying the thoracic inlet and the chest as a routine pre operative measure Often information of use to the surgeon will be forthcoming from this procedure

The following features may be determined from this examination

(*a*) The condition and situation of the trachea Often considerable tracheal compression arises in thyroid enlargement giving rise to serious respiratory embarrassment (see Fig 32) Frontal and lateral X ray projections of the thoracic inlet will usually demonstrate the extent of the narrowing of the trachea from this cause If the goitre is nodular indentations on the anterior surface of the trachea may be seen Similarly deviation of the trachea in this condition may be slight or marked

and its exact lateral or posterior deviation can be estimated Sometimes a tongue of thyroid will project downwards behind the trachea displacing it forwards the demonstration of this provides useful pre operative information (see Fig 33)

(*b*) Calcification within the thyroid This may be due actually to calcification in the walls of an adenoma or may occur in a haematoma



Fig 32 Thoracic inlet showing compression and deviation to the right of the trachea by a large goitre There is considerable calcification in the walls and within the enlarged thyroid

following haemorrhage within the thyroid In the latter event the calcification often has a flocculent appearance (see Figs 32 and 33)

(*c*) Retrosternal projection of the thyroid Retrosternal thyroid may arise as an extension of a clinically recognizable cervical goitre or the tumour may be entirely intra thoracic When there is intra thoracic extension the trachea is usually displaced backwards and there may be increased prominence of the aortic knuckle due to down ward displacement of the arch Often the downward projection from the cervical swelling is diffuse and bilateral but sometimes the intra thoracic mass projects markedly to one side from the mediastinal border On screen examination such a tumour can be confirmed as

thyroid tissue by observing its upward movement on swallowing Not uncommonly there may be calcification within the intra thoracic mass

With the advance in the treatment of carcinoma of the thyroid there

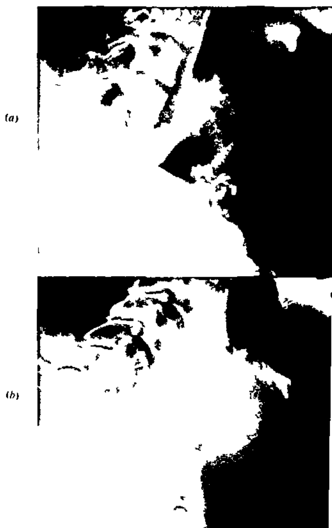


Fig 33 (a) Calcification in the thyroid lying anterior to the trachea The soft tissue space between the trachea is normal (b) Increase in the soft tissue space behind the trachea due to projection of the thyroid There is also compression of the trachea

are two further features which may be of clinical significance Metastases to bone from carcinoma of the thyroid present in about 50 per cent of cases as solitary osteolytic bone lesions They are usually well defined destructive bone lesions arising in the medulla and expanding

the cortex rarely producing any periosteal or other osteo blastic activity They often extend into the peri osseous tissues (see Fig 34)

Metastases from tumours in which the radio active iodine up take



FIG 34 Osteolytic metastasis with a large peri-osseous soft tissue swelling in the medial end of the right clavicle from a carcinoma of the thyroid

is considerable especially if they are in lungs may become more radio opaque due to their iodine content Their progress can then be observed by serial X ray examinations

CHAPTER 4

ALIMENTARY TRACT

RADIOLOGICAL examination of the alimentary tract in the hands of an *experienced radiologist has reached a very high degree of accuracy* Nevertheless in this sphere perhaps more than in any other a warning note must be sounded that this is merely part of and not the whole examination of the patient Radiological examinations are complementary to and should only follow full clinical examination It is perhaps true to say that in this field a positive X ray finding is usually significant but a negative result must always be accepted with reserve Even in this age of high X ray diagnostic accuracy there is still a place for the occasional exploratory laparatomy and in the presence of some such positive finding as a persistent occult blood a failure to detect an abnormality radiologically must be placed in its proper perspective alongside other clinical and laboratory data

(1) The Oesophagus

The value of radiological investigation of the oesophagus by barium examination has long been recognized and the appearance of cardio spasm carcinoma of the oesophagus and stricture of the oesophagus are familiar to all

It should be realized however that a full radiological examination of the oesophagus entails screen examination of the patient recumbent as well as erect and entails filling the stomach with barium in order to determine competence of the cardia and exclude hiatus hernia When therefore the radiologist is asked to investigate a problem such as dysphagia the request entails not just a barium swallow but barium examination of the oesophagus

Conditions which require some consideration are

(*a*) *Oesophagitis* Oesophagitis may exist without there being demonstrable or detectable radiological signs Its presence depends on the regurgitation of acid bearing gastric contents and the appear ances which may occur in this condition and on which a diagnosis may be made are —

(i) The demonstration at screen examination of free regurgitation *from stomach into oesophagus this may sometimes have the appearance* of a see saw or to and fro motion and especially in infants the flow may go from stomach to oesophagus and back again with each respiration

(ii) Spasm of the lower end of the oesophagus sometimes producing a serrated outline

(iii) The presence of an actual ulcer crater in the lower end of the oesophagus due to peptic ulceration

(iv) The presence of tertiary contractions throughout the oesophagus

Hiatus hernia is usually demonstrable in cases of oesophagitis and in long standing cases in which the inflammatory changes and ulceration have caused cicatrization stenosis of the oesophagus may be present (see Fig 35 (*a*))



Fig 35 (*a*) Hiatus hernia in a 7 year old child showing stenosis of the lower end of the oesophagus above the herniated part of the stomach

(*b*) *Hiatus Hernia* Full radiological examination will almost always reveal the presence of hiatus hernia It may be sliding or incarcerated

in type but long standing herniae tend to become fixed either by the development of fibrous tissue around the sac and peri oesophageal tissues due to local inflammatory changes or by cicatrical stenosis and shortening of the oesophagus

The surgical treatment of the condition is influenced by the presence or not of cicatricial changes in the oesophagus Radiological investigation of hiatus hernia therefore is directed not only to its diagnosis but also to demonstrating the state of the oesophagus its course and its point of entry into the stomach (see Fig 35 (*b*))



Fig 35 (*b*) Hiatus hernia There is a large herniated pouch of stomach para oesophageal in type but the oesophagus enters the stomach above the diaphragm

(*c*) *Oesophageal Varices* These commonly occur in cases of portal hypertension and are best demonstrated radiologically by means of portal venography which can conveniently be carried out by per cutaneous splenic injection However in the investigation of recurrent haematemesis barium examination of the upper alimentary tract is a simpler procedure and during the initial investigation of such cases the possibility of gastric or duodenal ulcer must usually be excluded

It is often possible to demonstrate the varicosities projecting into the lumen of the oesophagus when a thin coating of barium has been left lining the oesophageal mucosa (see Fig 36) It may be difficult to



Fig 36 Oesophageal varices

detect these small projections at screen examination and sometimes they will only be seen on films taken on expiration with the patient lying obliquely in the recumbent position Sometimes though present they make no indentation in the oesophagus in which case they lie

in the peri oesophageal veins rather than the sub mucosal veins It is important to realize therefore that failure to detect or demonstrate oesophageal varices at barium examination does not exclude their presence

(2) Stomach and Duodenum

The value of radiological investigation in the discovery of lesions in the stomach and duodenum is unquestioned The success of such investigations is dependent on careful and full screen examination by an experienced radiologist Nevertheless despite improvements in apparatus advances in technique and the most carefully conducted examination it is possible still to miss small lesions

In recent years there has been a very considerable increase in the number of cases referred for barium meal examination and it is unfortunately all too true that with the increased out patient work that has confronted clinicians and the welter of work referred for X ray examination there has been a tendency for the clinician to give the radiologist less information and for the radiologist to conduct his lists of barium examinations with insufficient clinical and laboratory knowledge of the case under investigation Only if this trend is overcome can any real further advance be made The ideal of consultation on every case is probably unattainable but surgeons and radiologists should certainly meet regularly to discuss problematical cases should devise a system of consultation over special cases and a system of advising the radiologist of the surgeon s operative findings (including the radiologist s successful diagnoses as well as his failures) for it is only by continuing to learn and by developing such conditions of mutual trust and confidence of understanding each other s problems that the best interests of the patient will be served

(*a*) *Congenital Hypertrophic Pyloric Stenosis* In infants the emptying time of the stomach is very variable up to 6–7 hr being within normal limits while delay in commencement of emptying can be due to pylorospasm induced by the artificiality of the barium feed and the surroundings of the X ray room The only radiological signs that are of true value are the demonstration of the narrowed and elongated pyloric canal (see Fig 37) and the visualization at screen examination of deep hyper active peristaltic waves

(*b*) *Haematemesis and Melaena* Haematemesis is a clinical problem into the early stages of which the radiologist does not usually enter Yet he is vitally concerned for sooner or later he will be asked to investigate most cases of haematemesis

Haematemesis may be spontaneous and unheralded or it may follow a long history of epigastric symptoms It may be single or recurrent small or massive The patient may appear little the worse for the episode or may be exsanguinated

The practice in many hospitals is to treat the patient and investigate him subsequently Many radiologists prefer to allow a period of three weeks to elapse on medical treatment before carrying out any examination of the upper alimentary tract Barium examination of the upper alimentary tract is a highly technical procedure and even in the most skilled hands is something of an ordeal for the patient In such cases as these it is important to find if possible the source of the bleeding Causes of haematemesis may be conditions such as hiatal hernia



FIG 37 Demonstration of the elongated pyloric canal in a case of pyloric stenosis

peptic ulceration of the oesophagus oesophageal varices gastric ulcer *ulceration of the surface of a gastric neoplasm such as a leiomyoma* duodenal ulceration or even upper jejunal lesions With so wide a variety of possibilities under consideration the examination must needs be thorough which means that it will be arduous for the patient certainly more than an exsanguinated patient can withstand Yet in spite of this it is a fact that routine X ray examination of such patients produces in many cases no positive finding It is of course likely that many bleeds are due to superficial erosions of gastric or duodenal mucosa which even at an early stage would not be detectable radiologically and which after three weeks of medical treatment have healed and so are no longer detectable Yet a negative result is a valuable and important contribution to the conduct of the case for it excludes the

other possibilities and gross pathology confirms clinical impressions and allows treatment to continue along established lines

In some cases of massive haematemesis where gastric ulcer is suspected and where the clinical condition of the patient may require emergency gastrectomy it is the practice in some hospitals to give the patient a cupful of barium or one of the newer water soluble media such as Gastrografin to drink and to take a series of films (sometimes even with a ward mobile X ray unit) in pre determined positions This will sometimes confirm the clinical diagnosis or possibly exclude gross pathology and so influence the immediate conduct of the case If such is the practice it is wise always to have this examination conducted and interpreted by the radiologist for the hazards of interpretation of barium films of the upper alimentary tract in differing conditions and positions such as these are too great to leave to the uninitiated and will only bring the practice into disrepute if indeed it does not cause actual catastrophe

Melaena is usually treated and investigated in the same way as haematemesis It may be due to the same causes but naturally if no cause is found in the upper alimentary tract the pursuit must be taken further and a small bowel examination and probably a large bowel examination carried out Bleeding from either a duodenal ulcer or less commonly a hiatal hernia is common in the experience of all surgeons and radiologists as a cause of melaena In the small bowel diverticulosis may give rise to bleeding and may be detectable radiologically A Meckel s diverticulum may give rise to haemorrhage and radiologists are often asked to demonstrate or exclude its presence It is rare for barium in the small bowel to enter a Meckel s diverticulum even if it exists and if it does exist and barium does enter it it is usually extremely difficult to be certain that the contrast medium is not just in another loop of bowel Cases have been published in which a Meckel s diverticulum has been demonstrated but this has usually been post operative confirmation of supposition and it is not commonly within the competence of radiologists to demonstrate this structure Thus requests for investigation to demonstrate or exclude its presence are of little value and the results may be misleading

If examinations of the upper alimentary tract and small bowel in cases of melaena yield no result then barium enema examination of the large bowel must be undertaken While it is recognized that bleeding lesions in the large bowel usually produce blood in the stools nevertheless altered blood may not uncommonly be passed from pathological conditions in the right half of the colon

(c) *Peptic Ulceration* This subject has been briefly mentioned in reference to haematemesis and melaena However only a minority of cases present with such definite positive signs and most cases suspected as having peptic ulceration of the stomach or duodenum present

with only a symptom complex Many cases create no difficulty to the radiologist and a positive diagnosis of gastric ulcer lesser curve or posterior wall or of duodenal ulcer is easily made In many other cases however diagnosis is less certain This may be because of inherent difficulties due to the habitus or posture of the patient Examination of a hypertonic stomach high under the sternal notch or of a squat thickset patient or of a hypotonic aperistaltic stomach in an asthenic individual or of a duodenum with a mesentery producing extra loops can produce technical problems which even the most experienced radiologist finds difficulty in overcoming In the stomach anterior wall ulcers admittedly a rarity may be missed In the duodenum if there has been a long history of symptoms compatible with ulceration the presence of scar tissue with its consequent fibrosis and puckering may render it impossible to demonstrate an active ulcer Radiologists have more and more come to rely on obtaining their graphic demonstrations of their screen examinations with a minimum of barium A little barium particularly if associated with gaseous distension demonstrates while much barium obscures In spite of this in spite of experience and of improvements in apparatus it is still possible to miss an ulcer or to mislead the clinician in charge of the case It is still true that while a positive radiological finding should usually prove correct a failure to demonstrate peptic ulcer in a case in which the clinical history and signs point very much to this diagnosis while usefully excluding grosser pathology does not positively exclude that condition In such cases grosser pathology having been excluded and other laboratory tests being compatible most clinicians are satisfied to treat their patients expectantly along symptomatic lines A radiological sign of some significance in arriving at a diagnosis of duodenal ulcer is punctate tenderness over the first part of the duodenum elicited with the patient in the erect position though often this same tenderness may be difficult or impossible to elicit in the supine position

One of the many difficulties facing the radiologist in examination of the duodenum is to interpret the significance of constant deformity of the first part of the duodenum when no ulcer crater can be demonstrated This sort of deformity may be due to fibrosis and scarring round a long standing ulcer it can also be due to carcinoma of the head of the pancreas and a tendency to diagnosis this latter condition as duodenal ulcer is one of the recognized errors of radiology of the upper alimentary tract

(d) *Retrograde Jejuno gastric Intussusception* Following gastro jejunostomy retrograde intussusception may occur either as an acute or a chronic condition The acute state may occur 7–10 days after operation and is probably due to oedema round the anastomosis with a loop of jejunum becoming locked in the oedematous stoma With continuous suction and attention to the patient s fluid balance the

oedema resolves and the intussusception reduces without further operative action The diagnosis can be confirmed by giving the patient an ounce of barium to drink and 30-60 min later taking a radiograph of the stomach—an examination which can be carried out with a ward portable unit (see Fig 38)



Fig 38 Retrograde jejuno gastric intussusception occurring 7 days after gastro jejunostomy has been performed

The chronic state is one which may not be suspected and which may not be detected for the intussusception if reducible may herniate into the stomach and be reduced several times during the course of an examination in fact the radiologist may be able to produce and reduce the intussusception at will by palpation

(e) *Anastomotic and Jejunal Ulcer* An ulcer at the stoma or in the jejunum just distal to the stoma is often difficult to demonstrate and the radiologist has often to change his technique using considerably less barium than is usual in carrying out a barium meal examination It is essential therefore when a request is made for a barium examination on a case that has previously had a gastrectomy that the fullest details of the type of operation carried out should be given The

radiologist must be in full possession of all the available information when conducting his examination

(*f*) *Gastro colic or Gastro jejuno colic Fistula* This rare late sequel to various forms of gastro jejunal anastomosis is sometimes suspected clinically and can be demonstrated radiologically However even if it exists it is rare for the fistulous connection to be demonstrated by a barium meal examination Barium enema is the examination that should be requested when this lesion is suspected and its presence will almost invariably be demonstrated by this route

(*g*) *Tumours of the Stomach* Radiological diagnosis of tumours of the stomach often bears no relationship to either clinical findings or the pathological state

In patients presenting with iron deficiency anaemia or pernicious anaemia and no detectable clinical signs surprisingly large gastric tumours may sometimes be found Not uncommonly extensive tumours of this type in which sometimes the clinical history may be very short are found at laparotomy to be operable with no obvious hepatic meta stases and no macroscopic lymphatic permeation Occasionally these large tumours which have been silent in growth are found on histological examination to be leiomyoma or neurofibroma though sarcomatous changes may arise in both This type of neoplasm on reaching large proportions sometimes ulcerates on its surface occa sionally producing a massive haematemesis radiologically it is thought that a large intra luminal tumour in the stomach with an ulcer or ulcers on its surface is likely to be either a leiomyoma (or leiomyo sarcoma) or neurofibroma (or neurofibro sarcoma) (see Fig 39) such a diagnosis is however only of academic interest for all gastric tumours are potentially malignant and require surgery It is however worth realizing that the size of a tumour bears no relationship to its malignancy and that provided clinical factors do not contraindicate it laparotomy is a proper procedure in even large tumours Similarly the most minute and radiologically innocent looking mass can prove at laparotomy to be widely infiltrative with extensive metastases

A question often asked is—how accurate are radiological methods in the early diagnosis of malignant disease of the stomach? As always with such investigations the degree of accuracy must vary with the experience of the radiologist Large tumours and extensive infiltrative scirrhus carcinomas are easy to detect and demonstrate Small tumours may easily be overlooked—especially may they be obscured by the use of too much barium Tumours either infiltrative or encephaloid in the pyloric antrum may be difficult to detect in the early stages Opinion as to whether lesser curve or posterior wall ulcer is simple or malignant can be extremely difficult to formulate certain definite signs of malig nancy exist the most important of which are (i) that intra luminal ulcers are usually malignant and (ii) that plateau or flat bottomed

ulcers are commonly malignant It is important to realize that what was at one time accepted as a clear indication of malignancy—great size of the crater—is no longer regarded in this light However,



FIG 39 A large tumour demonstrated in the stomach at barium meal examination Five separate ulcer can be identified on its surface Gastrectomy was performed and th tumour was found to be a neurofibroma

definite criteria that ulcers are simple are non existent This is not surprising as even histologists cannot always agree whether or not an ulcer is malignant or simple Anterior wall lesions may escape detection at even the most scrupulous examination but when detected are often malignant

To sum up then with regard to the diagnostic value of radiological examinations in this realm it can be stated that

(i) A positive diagnosis of a tumour is almost invariably correct Radiological differentiation between carcinoma simple tumour lymphosarcoma etc is only of academic interest is rarely possible with any degree of certainty and should not influence surgical conduct of the case

(ii) The site of the tumour as demonstrated by X ray examination e g the cardia or the pyloric antrum and the demonstration of involvement of the cardiac orifice or the pylorus may influence both the surgical approach and the conduct of the case

(iii) The size of the tumour may bear no relationship to its operability

(iv) The malignancy or otherwise of an ulcer may be no more easily determined by this form of examination than by gastroscopy or even histological examination All surgeons are familiar with cases of histologically simple ulcer dying within 12 or 18 months of gastrectomy from metastases History and clinical assessment of the patient may often be more reliable guides to the presence or otherwise of malignancy

(v) Doubtful or equivocal radiological findings in suspected cases should be followed up by gastroscopy and repeat X ray examination if not laparatomy

(vi) A negative result from a carefully conducted examination by an experienced radiologist probably means in the vast majority of cases that there is no tumour present It is of course possible for even the most experienced specialist to miss pathological processes just as it is possible for the surgeon at laparotomy with the viscus in his hand to fail to detect or recognize existing pathology On the whole however both contingencies are unlikely

(3) The Small Bowel

Radiological examination of the small bowel is notoriously difficult Meckel s diverticulum is rarely detected pre operatively Diverticulosis of the small bowel may be demonstrated though its extent may not be determined Conditions such as tuberculosis regional ileitis and tumours often become surgical emergencies before they present clinically

For satisfactory examination of the small intestine in the adult about two ounces of barium is the optimum amount of contrast medium i e considerably less than is used in examination of the stomach More than this tends to obscure rather than demonstrate small bowel lesions Thus the technique for radiological examination of the small bowel differs from that for examination of the stomach and duodenum and attempts to combine the two may lead to missing demonstrable pathology

Examination of the small bowel too is a time consuming procedure requiring frequent films and screen examinations of the patient over a period of up to 5 hr or even more and such examinations often require special arrangements to fit them into the time table of a busy department

It is important therefore that in making a request for a small bowel examination a surgeon should have a clear conception of the pathological condition that he is considering and the type of examination to which he is submitting the patient and which he is asking his radiological colleague to carry out

Regional Ileitis (Crohn s Disease) The belief that a positive diagnosis of regional ileitis is rarely made by radiological methods is misplaced In a recent series of 71 cases analysed in the author s hospital 42 of which had been X rayed there were positive radiological signs in 40 Though the positive radiological signs were missed at the time of the examination in 7 of these and only recognized retrospectively it remains on record that in 33 of the 42 cases investigated a definite diagnosis was made

The radiological signs vary with the stage of the condition its site extent and the presence or not of complications Some observers advocate examination by barium enema but most cases are demonstrated radiologically by a small bowel examination i e barium follow through In the patient with this condition who presents with a chronic history of bowel disturbance careful history taking and clinical examination will usually lead to a presumptive diagnosis of the condition E S R and occult blood examinations may give support to the diagnosis which can then finally be clinched by radiological investigation

Not all cases however present conveniently with such a chronic history many in fact are admitted to hospital as acute abdominal emergencies and the diagnosis is made at laparotomy Most surgeons prefer to avoid open surgery in regional ileitis in acute abdominal emergencies which settle or in sub acute obstructions where the diagnosis is in doubt and there are no positive signs for immediate surgery a conservative approach with full clinical laboratory and radiological investigation may often avert catastrophe and avoid the causation of troublesome fistulae and sinuses

The natural history of the disease is now regarded as consisting of three phases The phase of onset is characterized as being associated with anorexia tiredness and symptoms suggestive of a grumbling appendix The phase of physical signs usually manifests itself by diarrhoea abdominal pain anaemia a palpable mass and pyrexia The phase of complications presents as already discussed with signs of obstruction fistulae or even perforation

Radiological signs are rarely present during the first phase and probably arise somewhere between the first two phases In early disease

the radiological signs which may suggest the diagnosis are (i) changes in the mucosal pattern of the small bowel appearing as a constant ironing out of the mucosal folds (As a transitory appearance this may be within normal limits) (ii) Narrowing of the lumen of the bowel (iii) Loss of pliability of the bowel and possibly a localized mass or filling defect Because of the frequency of accompanying colitis it is essential to have also a knowledge of the state of the mucosa of the colon and so all cases should be investigated by barium enema as well as by barium follow through examination The radiological signs of advanced disease are (i) The string sign (Kantor s sign) described as an irregular linear shadow suggesting a cotton string in appearance extending continuously from the region of the last visualized loop of ileum through the entire extent of the filling defect and ending at the ileo caecal valve (see Fig 40) This may be due to spasm oedema or fibrosis (ii) Contraction and spasm of the caecum producing a conical shape (Stierlin s sign) (iii) A cone shaped contraction of the ileo caecal



Fig 40 Crohn s Disease Barium is shown in the terminal ileum and a positive String sign is shown

valve which may be embedded in a mass of fibrous tissue (iv) Dilatation of loops of bowel proximal to the stenotic lengths (v) The presence of fistulae demonstrated by barium tracking outside the bowel either in a blind track or connecting with some other part of bowel or with some other viscus such as the bladder

(4) The Large Bowel

Radiologists have learned over the years that barium in bulk often obscures more than it demonstrates and this applies especially to examinations of the colon Techniques therefore have been directed towards obtaining mucosal pictures of the colon and various practices such as the use of probanthine tannic acid veripaque and air replacement have been devised Individual radiologists all have their own preference All these procedures however are dependent on satisfactory preparation of the bowel in order to get rid of all faecal material

In spite of this it must be recognized that the detection of early lesions in the large bowel still leaves something to be desired Large intra luminal carcinoma diverticulitis established ulcerative colitis intussusception diffuse polyposis and amoeboma are conditions that are readily recognizable should not be missed by radiological methods and in the investigation of which this form of examination is a useful and essential diagnostic aid But annular carcinoma the early manifestation of intra luminal carcinoma and single polypi are lesions that may not be detectable even at the most scrupulous and painstaking examination

(*a*) *Ulcerative Colitis* The early stages of this condition are often difficult to demonstrate radiologically as the mucosal oedema swelling and hyperaemia can exist for a considerable time producing marked symptoms before any changes take place in the bowel wall which are detectable on the radiograph Thus changes seen at sigmoidoscopic examination such as reddened and angry mucosa that bleeds easily *may not be detected by radiological methods It is only when the* mucosal swelling is of an extent to obliterate haustrations or actual ulceration has taken place that the radiological confirmation becomes possible Thereafter as the ulceration becomes more progressive or pseudo-polypi become demonstrable and haustrations disappear from large segments of bowel or as the muscle coat becomes involved and the bowel assumes a ribbon like appearance the radiological diagnosis is simple and conclusive The role of radiological examination in the established case is

(i) To demonstrate the length of bowel that is involved (see Fig 41 (*a*))

(ii) To show the stage that the disease has reached in all the segments of involved bowel in particular where the disease has reached an

advanced stage to show the ability of the bowel to contract and distend (see Fig 41 (*b*))

(iii) To show whether or not the terminal ileum is affected (see Fig 41 (*b*))

(iv) To detect malignant change should this arise for carcinoma of



Fig 41 (*a*) Barium and air contrast in a case of ulcerative colitis affecting the transverse descending and sigmoid colon and the rectum There is no evidence of involvement of the caecum ascending colon or proximal part of the transverse colon

the colon not uncommonly develops in long standing cases of ulcerative colitis

(*b*) *Amoebiasis* Infection of the large bowel with Entamoeba histolytica commonly extends secondarily to the liver and local spread across the diaphragm into the thorax may occur Asymptomatic intestinal infections may occur but the common presentation is that of amoebic dysentery The diagnosis rests primarily on the recovery and identification of the parasites either in the amoeboid or cystic state from the stools from scrapings of rectal or sigmoid lesions or from necrotic debris expectorated or obtained by needling Radiology however has

some part to play as a means of demonstrating the extent of the disease and of its complications in known cases

The radiological appearances that may be encountered may be local in the large bowel or remote In the large bowel there may be changes of contour changes in the mucosal pattern or amoeboma The changes



FIG 41 (b) Advanced ulcerative colitis affecting the whole colon There is also involvement of the terminal ileum

in contour usually take the form of producing a narrowing especially of the caecum which may become funnel shaped In addition there is loss of distensibility of the affected part of the bowel and it assumes a *shaggy appearance* The changes *in the mucosal pattern are not* specific but consist of a loss of the normal mucosal pattern and replacement by a granular appearance with distortion by segmental spasm Amoeboma usually occurs in the right half of the colon it appears as a fixed space occupying tumour within the lumen of the bowel (see Fig 42)

The remote changes are due to complications—hepatitis liver abscess pleural effusion and lung abscess

Hepatitis causes diminished respiratory excursion of the diaphragm over the affected lobe of the liver which can be seen at screen examination Liver abscess may produce no obvious changes in contour but



Fig 4 Barium enema in a case of amoebic dysentery There is a large filling defect in the caecum *in which is a ragged lumen—an amoeboma*

if the liver enlarges upwards marked elevation of the diaphragm can occur The abscess cavity is not visible unless air replacement takes place either during aspiration or following perforation into a gas containing viscus If there are intra thoracic complications there is

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The radiological appearances that may be encountered may be local in the large bowel or remote In the large bowel there may be changes of contour, changes in the mucosal pattern or amoeboma The changes



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The remote changes are due to complications—hepatitis liver abscess pleural effusion and lung abscess

importance that they should not be missed—indeed the slogan 'Polyp detection is cancer prevention' has in it some element of truth. The greatest step forward in the radiological diagnosis of this condition has in the opinion of the author been the introduction of the routine use of tannic acid in the barium solution followed by air insufflation. The tannic acid added just before the examination so as to produce a 1½ per cent solution of tannic acid in the barium solution has two effects—having a slightly astringent effect it usually ensures good evacuation of the barium with collapse of the bowel and being at this strength very slightly irritant it has the effect of making a thin film of barium adhere to the bowel wall. Thus excellent mucosal pictures of the gut can be obtained. If the colon is then insufflated with air by means of a Higginson's syringe excellent demonstrations of great detail and of considerable diagnostic value can be obtained. The aim of such investigations is of course to detect polypi at the earliest possible time—a single rectal bleed will sometimes bring a patient for advice and it is in such cases that often great benefit can be achieved. It must never be overlooked that colonic polypi are often multiple and that if one is found search must be made for others. Unfortunately if preparation of the colon for the barium enema has not been effective a faecal residue can produce an appearance indistinguishable from a polyp (see Fig 43 (*a*)). It is in such



FIG 43 (*b*) A polyp in the transverse colon well demonstrated by air insufflation following evacuation of the barium enema. Note its base

almost always an associated pleural effusion really an empyema which may be extensive and inflammatory and destructive lung changes usually occur

Amoebic dysentery does not commonly produce strictures in the colon though rarely this can happen Bacillary dysentery, in contrast may leave severe and multiple strictures Radiology has no part to play during the acute phase of a bacillary dysentery and indeed no diagnostic aid other than laboratory facilities are required But in the investigation of altered bowel habit following severe bacillary dysentery such fib ous strictures may be found

(c) *Polypi and Carcinoma of the Colon* Small adenomata may be flat and sessile or may become polypoid and pedunculated They will commonly be obscured during complete filling of the colon with barium during barium enema examination and will only be detected on the mucosal films after evacuation of the barium or after air insufflation As polypi not uncommonly undergo malignant change it is of considerable



Fig 43 (a) Barium enema showing a long narrow segment at the hepatic flexure due to carcinoma of colon In the left half of the colon are multiple filling defects due to a considerable faecal residue any one of which could be due to a polyp

affected bowel is seen to be narrowed and irregular in outline—it has been described as having a saw tooth appearance the diverticula do not fill or not many of them do the barium entering as far as the neck but not into the saccule and during screen examination that part of bowel affected may be found to be palpably thickened tender and fixed



FIG 44 Diverticulosis of a long segment of the sigmoid and descending colon The lumen of the bowel though the bowel is slightly spastic is not narrowed and distended normally on air insufflation

cases that consultation between the surgeon and the radiologist is essential in the interests of the patient A useful diagnostic point is that while an adherent faecal residue never causes puckering of the bowel wall a polyp especially if its base is infiltrating may do so (see Fig 43 (*b*)) In any case of doubt where the clinical presentation was sufficiently strong to warrant it it is always worth while after full consultation considering repeating the examination after 8 or 10 weeks It is also worth realizing that sometimes the radiological examination may give a more reliable assessment of the state of affairs than manual examination of the bowel at laparotomy by even an experienced surgeon The author has known a case where a radiological diagnosis of carcinoma of the colon accom panied by a polyp at some distance from the main lesion was made yet at operation dealing with the operable carcinoma the surgeon failed to confirm the presence of the distant polyp only to have to re open the patient two years later for what was now a second carcinoma at the site of this distant polyp As stated already polyps or carcinomas are occasionally multiple and after successful resection of one it may be in the interests of the patient to repeat the radiological examination of the colon at intervals of say two years or more frequently if significant symptoms supervene In such cases it may be possible to demonstrate early recurrence at the site of resection

(*d*) *Diverticulitis of the Colon and Carcinoma* Diverticula of the colon are a common finding (see Fig 44) Occasionally a few or even solitary diverticula are found in the right half of the colon but by far the com monest site to be affected is the sigmoid colon The presence of diver ticula does not necessarily mean that inflammatory changes must exist though stasis in them does predispose towards the development of inflammation Stasis in these small pouches of bowel is a very common feature and often a film of the abdomen 7–10 days after a barium meal or barium enema will reveal a barium residue in them In such conditions stagnation is inevitable providing an excellent medium for the develop ment of inflammation Considering how frequently diverticulosis is discovered at routine examinations it is surprising how few of the persons so affected have positive radiological signs of diverticulitis It is probable of course that many of the diverticula do in fact become inflamed from time to time producing bowel symptoms of varying degree but that these intermittent transient and minor episodes are insufficient to produce pathological changes capable of producing radiological signs

Detectable radiological signs of diverticulitis are due to extensive and probably longstanding pathological changes As the sacculae become inflamed and the inflammation spreads to the surrounding tissues in the bowel wall the neck of each diverticulum becomes either spastic or oedematous and the whole bowel in the involved segment becomes thickened and irritable At barium enema examination the

(a)

(b)



FIG 46 (a) Lateral projection during filling of the large bowel at barium enema examination showing the narrow segment at the recto sigmoid junction in a case of Hirschsprung's disease (b) A P projection of the same case after evacuation of the barium showing the collapsed rectum and the grossly dilated sigmoid colon

Carcinoma not uncommonly occurs in association with diverticulitis or as a complication of it Most surgeons of any experience have been faced at laparotomy with an inflamed mass in the sigmoid colon which they have been unable to diagnose definitely as diverticulitis or an inflammatory mass round a carcinoma The same problem exists at radiological examination and it is often not possible to exclude the possibility of co existent neoplasm indeed it may not be in the best interest of the patient for the radiologist to try to exclude the presence of neoplasm when faced with advanced diverticulitis though there are occasions when he can definitely point towards the likelihood of its presence

The role of radiological examination in this is therefore—(i) to establish a diagnosis of diverticulosis and demonstrate its extent (ii) to diagnose diverticulitis if positive signs are present and to demonstrate its extent (iii) to demonstrate changes in the lumen of the bowel (i e narrowing) if any in the affected segment and especially show the ability of the bowel proximal to the affected segment to empty itself of its contents at evacuation (iv) to show any of the possible complica tions that may arise e g the co existence of neoplasm the existence of

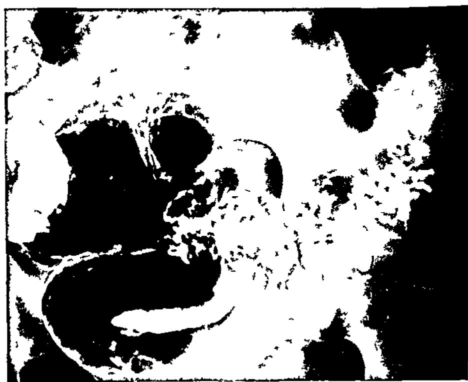


Fig 45 Diverticulitis of the sigmoid colon This film was taken after air insufflation following evacuation The rectum and descending colon are well distended by the air but the sigmoid colon remains narrowed One of the complications of this condition namely a Colo vesical fistula is demonstrated there being barium in the bladder

CHAPTER 5

DISEASE OF THE BILIARY TRACT

RADIOLOGICAL investigation of the biliary tract may be classified as pre operative operative and post operative

(1) Pre-operative

(*a*) *The Technique of Cholecystography as a Diagnostic Test* The test is well known and requires no full description it consists of the oral administration of an organic iodine compound (there are many Phenìodol Telepaque Biloptin Biliodyl etc) and the taking of films during a period ranging from 11–16 hr later When a satisfactory demonstration of the gall bladder has been obtained a further oral administration is given of a substance containing fat or oleum arachis or even a meal with eggs and butter and then subsequently further films are taken during and after contraction of the gall bladder During the course of the examination films are taken with the patient both prone and erect

If no satisfactory demonstration of the gall bladder has been obtained before administration of fat and this failure of visualization is not due either to the patient having vomited the contrast medium or to pyloric stenosis a second dose of the compound can be given the following night and whole procedure repeated This will sometimes provide visualization of the gall bladder Occasionally the oral contrast medium produces intestinal hurry or diarrhoea but this rarely if ever interferes with absorption of the medium poor concentration by the gall bladder should not be ascribed to this factor

Tomography as described later may be of very great help in obtaining good demonstrations of the gall bladder if it is being obscured by overlying faecal and gaseous bowel shadows

Cholecystography can only be regarded as a test of gall bladder function if the possibility of liver disease can be excluded Further it is useless to carry out these investigations in the presence of jaundice as visualization of the gall bladder will not be obtained even with a history of jaundice having disappeared as long as 2 or 3 weeks failure to visualize the gall bladder may still occur

Interpretation of the results of cholecystography is not always simple and should never be divorced from the clinical aspects of the case under investigation The radiological investigation is not the final arbiter of gall bladder disease but merely one factor in the full clinical examination of the patient The following generalizations therefore though

para colic fistulae or colo vesical fistulae (see Fig 45) (v) *to exclude* pathological conditions from the remainder of the large bowel

(e) *Hirschsprung's Disease* This condition due to an aganglionic segment of sigmoid colon is now differentiated from megacolon and its surgical treatment by recto sigmoidectomy is an established practice It sometimes presents in the first few days or weeks of life mimicking a neo natal obstruction but often the onset is insidious with constipation and increasing abdominal distension becoming gradually more apparent The differential diagnosis from megacolon is made by rectal examination but once megacolon has been excluded it is essential to confirm the diagnosis of Hirschsprung's disease This is done by barium enema examination with in addition to the routine films a radiographic *demonstration in the lateral projection (see Fig 46)* This *shows* not only the narrow constriction at the recto sigmoid junction or in the sigmoid colon but also its length which may in some cases be as much as 10 or 12 in

In carrying out this examination it is important not to fill the colon completely with barium as this may take several pints and will cause even greater colonic stasis It is wise also to take a further film after evacuation and if there is much barium residue to give colonic lavage until the residue is cleared

(2) Operative Examination of the Biliary Tract or Cholangiography

This procedure can be carried out either in the operating theatre during cholecystectomy after insertion of a cannula or some days later in the X ray department when drainage has been carried out and a T tube left in

Injection of the contrast medium is made through the cannula or T tube and thus a demonstration of the common duct and hepatic ducts obtained (see Fig 47) The medium flows into the duodenum



FIG 47 Operative cholangiogram The common hepatic duct and common bile duct are slightly dilated and there is a small round non opaque calculus at the distal end of the common bile duct

and occasionally retrograde filling of the pancreatic duct may occur (see Fig 48) The main use of this procedure is to demonstrate stones in the common duct

broadly true must always be referred back to the patient under examination and interpreted in the light of all the clinical data especially bearing in mind that pancreatic disease often interferes with gall bladder function and with demonstration of the biliary tree

(i) The demonstration of gall stones is an indication of gall bladder disease Non opaque cholesterol stones however can occur in a gall bladder showing no signs of inflammation but of course may give rise to biliary colic

(ii) A well functioning gall bladder is an indication of normality and excludes the likelihood of chronic cholecystitis Nevertheless just occasionally probably in not more than 1 per cent of cases of chronic cholecystitis the gall bladder will continue to concentrate the contrast medium well

(iii) Non function by the gall bladder indicates gall bladder pathology and is usually evidence of chronic cholecystitis

(iv) Impaired concentration by the gall bladder indicates gall bladder pathology usually chronic cholecystitis Grossly impaired concentration is not difficult to recognize but lesser degrees of impairment may be *difficult to decide Most radiologists take an arbitrary base line* a gall bladder shadow as dense as or denser than the shadow of the patient s lower ribs is regarded as evidence of normal function a shadow less dense than the lower ribs is regarded as evidence of impaired function

Failure of the gall bladder to contract after administration of fat should not be regarded too seriously as a criterion of impaired function Individuals vary very considerably in their response Failure to contract in the presence of poor concentration can however probably be regarded as further evidence in favour of pathology

The main value of the films taken after administration of fat is that the altered gall bladder shape may bring to light gall stones not previously noted and that the cystic and common ducts are frequently demonstrated

(*b*) *The Technique of Combined Cholecystangiography* This technique is coming into general use it consists of oral cholecystography as already discussed followed by intravenous injection of 20 ml of Biligrafin Forte about 12 hr after the oral administration when the first film has already been taken but before administration of fat Further films are taken as required up to 40 min after the injection to demonstrate the whole biliary tree When this has been identified satisfactorily fat is given and the investigation proceeds as for oral cholecystography

By this method the hepatic cystic and common ducts can be visualized as well as the gall bladder and so a more comprehensive examination of the biliary tract is carried out

or alternatively deferred to the X ray department if a drainage tube has been left in If the investigation is to serve any useful purpose only films of the highest quality should be regarded as acceptable

(3) Post-operative

The persistence or return of symptoms following cholecystectomy is one of the problematical clinical pictures with which surgeons are



FIG 49 Intravenous cholangiogram of a patient with symptoms of dyspepsia and on whom cholecystectomy has been performed 4 years earlier The common bile duct and common hepatic duct are dilated and contain multiple non opaque gall stones

sometimes faced The occurrence of persistent right hypochondriacal pain or of distension or occasionally of jaundice merit further investigation

Intravenous cholangiography is the method of investigation in these cases Twenty to forty millilitres of Biligrafin Forte are injected and films taken at intervals during the hour following injection By this method the common hepatic and common bile ducts can usually be well visualized the cystic duct stump may also be seen

In normal cases the average width of the hepatic duct and of the

There are two pitfalls in carrying out cholangiography Air bubbles not uncommonly get into the cannula or tube and are carried along with the contrast medium into the common duct When a film is then exposed these air bubbles are shown as filling defects in the contrast filled common duct and may be misinterpreted as stones This seems to occur more frequently with oily media than with watery media



FIG 48 Operative cholangiogram showing normal hepatic ducts and common bile duct There has been reflux into the pancreatic duct

and for this reason it is preferable to use diodone or any water soluble medium rather than Neo hydriol Also it is wise to inject a reasonable quantity of the medium say up to 12–15 ml in order to flush such air bubbles through into the duodenum before making an exposure And finally at least two films should be taken a further injection having been made between the two exposures air bubbles shift or change shape with a further injection stones remain constant

The other pit fall arises from trying to do operative cholangiography in the theatre on bulky patients with portable X ray apparatus of insufficient output Films taken under such conditions are rarely of diagnostic quality and may be misleading Cholangiography should only be carried *out in the operating theatre if the conditions are ideal,*



FIG 50 Tomogram of common bile duct during intravenous cholangiography The duct is shown to be grossly dilated and to contain a large non opaque gall stone

(5) The Pancreas

In the adult pancreatic disease may present in a variety of ways It may simulate biliary tract disease it may produce vague recurrent dyspepsia or anorexia or it may have a more dramatic onset and presentation as in acute pancreatitis The latter is a differential diagnosis always to be considered in the investigation of any acute abdomen especially when the history and clinical signs are obscure Radiological methods have their part to play in the investigation of such problems and while diagnostic criteria may be few or difficult to interpret yet when viewed alongside clinical examination and other laboratory tests may often contribute valuable information to an assessment of the whole problem

In examination of the acute abdomen in which acute pancreatitis is a possible clinical diagnosis the role of radiology is by plain X ray examination of the abdomen (i) to exclude other possible abdominal pathology especially complete mechanical intestinal obstruction (ii)

common duct lies between 5–15 mm A width greater than 15 mm should be regarded as dilatation of the duct The lower end of the common duct is poorly demonstrated in normal cases and appears funnel shaped, this is the narrowest portion of the duct being embedded in the head of the pancreas and the wall of the duodenum A dilated duct usually loses its funnel shape and its lower end appears cigar shaped and is often well seen in contrast to the poorly seen normal lower end In normal cases the right and left hepatic ducts are usually not well seen but are more readily demonstrated when some degree of obstructive dilatation of the lower biliary tree is present An occasional cause of confusion is that the contrast medium entering the duodenum and mixing with duodenal contents often passes retrogradely to the first part of the duodenum pooling there and casting a shadow that appears like a re forming gall bladder

The pathological changes that may be demonstrated in these cases are

(*a*) Common duct stones which may be present in either an undilated or a dilated duct (see Fig 49)

(*b*) Stones in the cystic duct remnant

(*c*) Stenosis of the duct system If strictures occur they are usually at the original site of entry of the cystic duct and are probably due to fibrosis following leakage of infected bile round the bile duct

(*d*) Dilatation of the common duct without the presence of stones Spasm of the sphincter of Oddi has been suggested as a cause in these cases but *it seems equally possible that the dilatation may have* occurred before cholecystectomy and that any stones that were harbouring in the duct and causing obstruction have subsequently been passed

(4) Technical note—Tomography

Tomography may be of help in obtaining satisfactory demonstrations of the biliary tract In tomography by movement of the X ray tube and film in opposite directions during the exposure at speeds proportional to each other the shadows of unwanted structures can be eliminated by blurring them This leaves a plane in focus In investigations of the biliary tract bowel shadows may often obscure the area under examination or it may not be possible to determine whether or not a particular shadow is inside the gall bladder or bile ducts The most fruitful field for the application of this technique is in post cholecystectomy investigation of the common duct to find whether or not duct stones exist (see Fig 50) In such examinations it is essential to be quite certain that stones are or are not present The technique has been further simplified by the introduction of the multi layer tomograph cassette by means of which any number of layers 1 cm apart up to a maximum of 5 (or in some cases 7) can be examined with a single exposure to the patient

There may however be calcification in the pancreas in long standing cases the calcification can be massive and diffuse or punctate it can spread extensively throughout the pancreas or be confined to the head or body or tail Barium examination in such cases may show



FIG 52 Barium meal examination confirming the diagnosis of carcinoma of the head of the pancreas *The mucosal pattern of the second and third parts of the duodenum has been almost completely obliterated*

radiological signs of steatorrhoea with disordered motor function with widened or absent mucosal folds in the upper small bowel and a tendency for the barium solution to precipitate and clump

Pancreatic cysts either as a result of trauma or chronic infection may occur in any part of the gland They vary in size and radiological signs vary accordingly They produce characteristic round smooth indentation of neighbouring viscera without any fixation of the surrounding tissues (see Fig 51) Barium examination will often contribute to or confirm the diagnosis and anatomical site of this condition

Carcinoma of the pancreas is often insidious in growth and may only

possibly to contribute towards a positive diagnosis by demonstrating either or both of the following (*a*) marked gaseous distension of the stomach with a normal distribution of gas throughout the remainder of the gut (*b*) distension of loops of bowel both small and large and



FIG 51 Barium meal showing the impression of a large pancreatic cyst on the pyloric antrum of the stomach and on the third part of the duodenum

especially of the transverse colon in the upper abdomen with stasis in the distended loops but without evidence of obstruction Where the clinical presentation is less acute but acute or sub acute pancreatitis is still considered a possible diagnosis on clinical grounds barium examination of the upper alimentary tract may provide useful con firmatory evidence Ileus of the stomach duodenum and upper jejunum with swelling of the mucosal folds of the duodenum and upper jejunum may be demonstrated in these cases or the stomach may be elevated or displaced by the enlarged pancreas

In cases of chronic pancreatitis there may be no radiological signs

CHAPTER 6

THE URINARY TRACT

RADIOLOGICAL investigation of the urinary tract has now reached a high degree of diagnostic accuracy but this is dependent on a very strict observation of and control of technical factors So much useful information about the urinary tract particularly the upper urinary tract can be obtained by the routine use of the available techniques and so much reliance has come to be placed upon them that it is absolutely essential that only first class films from such investigations be considered acceptable This can only be the case when there is the closest co operation between surgeon and radiologist and when the radiologist who in most hospitals carries out the examination is in full possession of the clinical facts of the problem under investigation It is essential that the whole of an examination should be under the control of the radiologist and not just left to a technician for often decisions can be made during the course of the examination to vary the technique and so bring to light further data which will not only help to establish the diagnosis but also influence the approach to treatment

(1) Techniques of Investigation

The methods of examination include

(*a*) *Excretion Urography* The greatest aid in the everyday elucidation of clinical problems in this field comes from the use of this technique The contrast media in current use can be injected intravenously or after dilution with distilled water to a concentration of approximately 15 per cent (i e an isotonic solution) can be given subcutaneously with hyalase Important factors in the successful carrying out of the examination are the restriction of the patient s fluid intake prior to the examination and the application of compression to the lower abdomen after the first post injection film has been taken

The person conducting the examination will not hesitate to administer a second injection 20–30 min after the first if it is apparent from the first films that concentration of the medium by the kidneys has been unsatisfactory or that a particular point in diagnosis has not been cleared up satisfactorily

(*b*) *Retrograde Pyelography and Ureterography* This is carried out by injection through the ureteric catheter after it has been inserted at cystoscopy When a patient has been thus submitted to instrumentation it is essential that the radiographic quality of the films should only be

be diagnosed at laparotomy Radiological diagnosis can only be made if there is deformity of the surrounding structures The commonest site for carcinoma is in the head of the pancreas and often there will be displacement of the barium filled duodenal loop widening of the loop or even infiltration of the duodenum with fixation and disappearance of the mucosal folds on its inner aspect (see Fig 52) Similar involvement of the stomach may also be noted Routine barium examination of patients who have exhibited jaundice for an unduly long time will sometimes provide a positive diagnosis in this field and as the surgery of the condition has made great strides in recent years any diagnostic aid which will establish earlier diagnosis must be directed to this end Radiological help in the diagnosis of tumours of the body and tail of the pancreas is less certain but if attention is paid to the anatomical site or displacement of normal viscera signs may sometimes be obtained which add additional weight to clinical suspicions

(*d*) *Renal Puncture* This technique is described in detail in the section on Renal Tumours

(*e*) *Retro peritoneal Pneumography* This consists of introducing a gas—air oxygen or carbon dioxide—into the retro peritoneal space It can be introduced either by the pre sacral route or by injection over the iliac crests

If the pre sacral approach is used a preliminary film with the patient in the lateral position will show the thickness of the post rectal fascial plane Under local anaesthesia and strict aseptic procedure a wide bore needle is then introduced lateral to the coccyx or lateral to the sacro-coccygeal junction into this space A syringe is attached to the needle and withdrawn to make certain that the tip of the needle is not in a blood vessel and the gas then introduced It can be injected using a syringe with a two way attachment or it can be run in under hydrostatic pressure though this method is usually not satisfactory as it takes too long or it can be run in by regulated flow from a gas cylinder Whatever method is preferred a sterile filter is used and for an adult patient 1000 ml is required The use of carbon dioxide eliminates the danger of gas embolism but its disadvantage is its rapid absorption and many radiologists prefer to use air or oxygen When the injection has been completed the patient is made to sit or walk about for 20–30 min to allow the gas to ascend along the retro peritoneal space to the peri renal planes

If the injection is made over the iliac crests the site of injection is 1 in above iliac crest 4 in to either side of the mid line thus requiring two injections A sharp needle can be felt piercing three separate tissue planes the subcutaneous fat the muscle and the fascial sheath There is little or no danger of puncturing bowel as the latter usually recedes from the needle point Four hundred millilitres of gas are injected over each iliac crest by this route the procedure is painless and if pain is experienced by the patient this is indication that the needle has not been introduced far enough and that gas is being forced into muscle planes By this approach the gas reaches the renal areas sooner

By this technique the kidneys can be outlined by contrast against the gas in the peri renal tissues Space occupying lesions causing enlargement of the whole kidney or localized enlargment of part of the kidney can thus be demonstrated The supra renal glands can be shown and it is the one satisfactory radiological method of demonstrating supra renal tumours

(*f*) *Tomography* The procedure of tomography is very useful in renal investigations By this technique in which the X ray tube and film are made to move in directions opposite and at speeds proportional to one another unwanted shadows are blurred leaving in focus only the shadows of structures relevant to the examination The shadows of overlying bowel often confusing in kidney investigations can be

the very finest This can rarely be obtained in the operating theatre with mobile X ray apparatus High output apparatus with the use of a Potter Bucky diaphragm to improve definition are essential It is preferable too for the patient to be conscious and able to co operate by holding his breath When a satisfactory demonstration of the renal calyces and pelvis has been obtained it is important to withdraw the catheter by a length that can be estimated from the preliminary film and then make a further injection and take further films to demonstrate *the ureter No such examination can be considered complete until* there is a satisfactory ureterogram as well as pyelogram

(c) *Renal Arteriography* This can be carried out either by direct puncture of the aorta above the level of the renal arteries or by per cutaneous puncture of a femoral artery and retrograde catheterization with a polythene catheter The latter method is probably both easier and better it requires a puncture needle of wide internal diameter and a polythene catheter with a curved tip through which a metal leader can be threaded The leader is of the same length as the catheter and can be observed under screen examination Under local anaesthesia and by percutaneous puncture as for femoral arteriography the catheter and leader are introduced through the puncture needle into the femoral artery and then retrogradely into the aorta under screen control When it is considered that the tip is at the level of the renal artery the leader is withdrawn slightly and the catheter rotated until it enters the renal artery the fact that it has done so can be confirmed by re introducing the leader to its full length By this method selective renal arterio graphy of one or other kidney can be carried out by withdrawing the leader and injecting rapidly only 7–10 mls of contrast medium through the catheter Alternatively if it is preferred to demonstrate both kidneys the catheter can be passed beyond the level of the renal arteries and 30 ml of contrast medium injected some of the contrast medium will be lost to the coeliac axis and some down the main trunk of the aorta but by this method it is possible to demonstrate both kidneys simultaneously and thus to compare them Furthermore by this method aberrant renal arteries will be demonstrated which may be missed by the selective approach

If the instruments for this method are not available aortography can be simply carried out by the translumbar approach to direct aortic puncture and 30 ml of contrast medium injected rapidly This is described more fully on p 138

For either method it is essential to have some form of rapid film changer so that films can be taken in quick succession—up to 6 or 8 films in a minimum of 6 or 8 sec accordingly By this technique it is possible to show anomalies of vascular supply to the kidney infarcts and renal tumours and to investigate fully cases of tuberculosis and haematuria

perspex rest At its other end is a rubber nozzle into the distal half of which an inch of narrow rubber tubing is threaded This latter is passed through the external meatus into the distal end of the urethra and the nozzle fits into the meatus to make a water tight joint A syringe can then be fitted to the other end of the steel tube

The bladder is first filled with about 150 ml of contrast medium, any of the standard contrast media diluted to about 15 per cent may be used This will produce a shadow of adequate density without obliterating other useful landmarks or abnormalities The syringe is then filled with contrast medium of about 50 per cent strength and a further 4 or



Fig 54 Cystourethrogram showing a stricture of the urethra with a false passage around the stricture a small urethral diverticulum proximal to the stricture elongation of the supra collicular part of the urethra due to prostatic enlargement and a bladder diverticulum

satisfactorily blurred It is a time consuming and extravagant procedure and should never be regarded as a routine technique Conventional methods are very satisfactory in most cases but tomography can be used as a supplement to some investigations by excretion urography and *should always be used in conjunction with retro peritoneal pneumo* graphy In this latter procedure it is essential to be able to dissociate the shadows of bowel gas from injected gas It is also a useful pro cedure as a routine when investigating infants or young children by excretion urography Air swallowed during crying following an injec tion will quickly pass into the small bowel distending it and badly obscuring the kidneys Tomography will eliminate these

(*g*) *Cysto urethrography* This technique which combines examina tion of the bladder with examination of the urethra can be carried out *out on males or females*

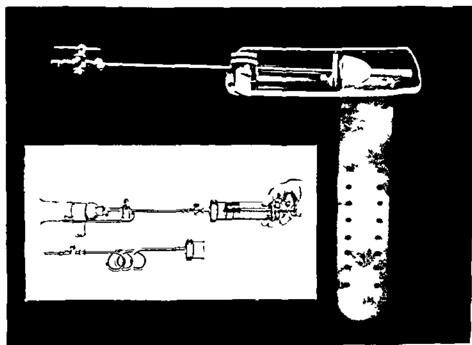


Fig 53 The instrument used for cysto urethrography The inset shows the instrument attached for urethral filling during radiographic exposures Normally a long rubber connection is used to enable adequate protective measures against X rad ation to be taken

(*a*) In males some form of special instrument is required through which injections can be made and by means of which a water tight nozzle at the external meatus can be made A simple instrument which can be made *in most hospital workshops is illustrated in Fig 53* It consists of a curved perspex rest on which the penis lies held in position by a broad rubber band fastened round it A long hollow stainless steel tube with a tap at its proximal end is held by a clamp fixed to the

taste in the mouth sneezing nausea or vomiting (*b*) a peripheral circulatory collapse with a fall in blood pressure pulselessness, a sensation of coldness sweating or fainting Death may occur from peripheral circulatory failure, (*c*) an allergic or anaphylactic effect with the appearance of weals urticaria peri orbital or peri oral swelling or even oedema glottidis, or (*d*) a convulsive reaction apparently due to generalized irritation of the central nervous system which may result in death from irreversible coma This last type is extremely rare, and indeed all the severe reactions are rare

Iodoxyl (trade names Uroselectan Pyelectan etc) is not now widely used for intravenous examinations Its effects were mainly local—venous spasm and thrombosis If peri venous injection is inadvertently made with this medium an unpleasant tissue reaction with local inflammation possibly even causing a slough may occur It contains two iodine atoms in its molecule *Diodone* (trade names Pyelosil, Uriodone Diodrast etc) rarely produces local effects and peri venous injection has no untoward results it can in fact be used in 12–15 per cent solution with hyalase for sub cutaneous injection This medium occasionally produces either an anaphylactic or hypotensive result commonly in their mildest forms but sometimes to an alarming degree It contains two iodine atoms in its molecule *Sodium Acetrizoate* (trade names Urokon Diaginol) Comparable in its results with diodone this medium also produces similar effects It contains three iodine atoms in its molecule

Hypaque is the trade name of *Sodium Diatrizoate* prepared usually in 45 per cent strength The unpleasant sequelae from this medium are far fewer than any of the media so far mentioned but anaphylactic and hypo tensive reactions have been reported in the U S leading in a few cases to death It contains three iodine atoms in its molecule

Urografin is the trade name of a substance differing from Hypaque only slightly in one chemical side claim which is claimed to lessen its toxicity It is prepared in 60 per cent and 76 per cent strengths It contains three iodine atoms in its molecule

In the hands of the author 45 per cent Hypaque and 60 per cent urografin are the media of choice, both producing adequate density and both having low toxicity Hypaque is the easier to inject being slightly less viscous It must be recognized however that there have been fatalities following the use of most media and so precautions must be taken to combat any possible reactions These should be as follows

(i) All likely instruments materials and drugs should be available at all times in the urography room e g syringes needles laryngoscope endo tracheal tubes oxygen cylinder with mask 1 1000 adrenaline 10 per cent calcium gluconate thiopentone phenylephrine There should be a known drill to follow in the event of emergency

(ii) Any patient with an allergic history (e g hay fever asthma

5 ml are injected During this injection an oblique film of the bladder and urethra is taken This is processed and viewed and any other films necessary to elucidate any doubts are then taken When these have been viewed an oblique film is taken with the patient micturating If possible micturition is carried out against the pressure of the instrument still in place as this opens out the posterior urethra well If this cannot be achieved the oblique film is simply taken with the patient micturating normally into a container A final antero posterior film is always taken after micturition to show any residue in the bladder

This technique can be used to demonstrate bladder diverticula their size extent number and any residual urine in them micturition abnor malities of the bladder the bladder after operation middle lobe enlargement of the prostate chronic prostatic abscesses urethral strictures their site and length and other urethral anomalies (see Fig 54)

(*b*) In the female no injection films to show the urethra are taken The patient is catheterized and the contrast medium injected through the catheter If the problem under examination is in the bladder a 15 per cent strength of one of the organic contrast media is satisfactory If however it is necessary to show the urethra lateral films will be necessary during micturition and dense contrast medium about 50 per cent strength is required Films are taken as required If it is necessary to show the urethra as is necessary before or after some gynaecological repair operations lateral films are taken—one at rest one on bearing down and one on micturition These are best taken with the patient erect but if micturition is to take place satisfactorily in this position it is wise to devise a rubber bag attachment for the patient to wear

(2) Contrast Media

Many of the contrast media that have been used for intravenous injection in excretion urography (or for intra vascular injection in all vascular radiography) have unpleasant and undesirable side effects From this point of view the perfect contrast medium has not yet been produced

The radiologists requirements are that the medium should produce a shadow of adequate density be easy to inject and produce no un pleasant sequelae There are many available that produce shadows of good density Most are easy to inject though some of the higher con centrations compare unfavourably with others owing to their increased viscosity Almost all produce some unpleasant side effects though in some of the newer products these have been reduced

These side effects may be local or general The local effects may be pain at the site of the injection venous spasm or venous thrombosis The generalized effects may be (*a*) mild toxic effects such as warmth a

out patient radiological examination may make it expedient for cysto scopy to be carried out on the patient as an in patient rather than as an out patient and so eliminate unexpected difficulties

When excretion urography and laboratory tests have been completed consultation between the surgeon and radiologist should take place For more than a decade the author has sat down once a week with his colleagues the genito urinary surgeons to go through the clinical notes review the laboratory findings and present the radiological findings of all their current cases under investigation Each has learned the prob lems difficulties and point of view of the other and all including the patients have profited At this consultation any further steps employ ing radiological aid can be planned No such steps may be required for the surgical course may now be plain It may however be decided that following cystoscopy retrograde pyelography of one or both kidneys is required to clear up some point The radiologist being aware of the problem as a result of this consultation will direct his attention at subsequent pyelography to obtaining a clear diagnostic solution to the problem Alternatively it may be decided that the next step still lies with the radiologist to carry out cystography or cysto urethro graphy or renal puncture to confirm or establish a diagnosis

Occasionally when all clinical radiological laboratory and cysto scopic investigations have been carried out no clear picture has emerged It may be that repeated intermittent haematurias have occurred and yet no definite pathology has been found Or it may be that at cysto scopy the blood has been seen to be coming from one ureter and yet excretion urography and retrograde pyelography have revealed no abnormality in the kidney on that side Such a state of affairs especially if it is in a middle aged or young adult is an indication for renal arterio graphy possibly by aortography so as to demonstrate both kidneys at the one examination This examination may reveal a small lesion such as a tumour previously unsuspected requiring active surgical inter vention

(4) Urinary Calculi

Urinary calculi usually contain calcium in some form and so cast a shadow on a radiograph Their site and effect on renal function can be determined by excretion urography By this method therefore it can be shown whether they are single or multiple unilateral or bilateral calyceal pelvic ureteric or vesical It can also be shown whether there is a chronic pyelonephritis or hydronephrosis associated with the cal culus whether there is impairment or loss of renal function The whole urinary tract can thus be assessed and the course of treatment to be adopted can be decided After either their removal by surgical methods or their passage by the normal route the improvement of renal function and form can be observed and recorded and by subsequent follow up it can be seen whether or not a calculus is re forming

eczema allergy to penicillin) should be given in inti histamine during the 24 hr before the examination 16 mgm of Piriton taken in 4 mgm doses over this period have been found satisfactory

(iii) In the event of any reaction release abdominal compression and administer 100 per cent oxygen with an airway if the patient is uncon scious

(iv) If the reaction is severe and anaphylactic in type give 0 5 ml 1 1000 adrenaline subcutaneously followed by 20 ml of 10 per cent calcium gluconate intravenously

(v) If the reaction is severe and hypotensive in type give 1 mgm phenylephrine by intravenous injection or 5 mgm intramuscularly if no vein is accessible

(vi) If the reaction is convulsive in type give 150 mgm thiopentone intravenously and repeat if the convulsions have not ceased in 5 min

(3) Haematuria

Radiology plays an essential part in the investigation of any case of haematuria The important feature is to regard this merely as a part of the complete investigation of the patient It is neither the complete answer in any case nor can it be ignored

A story of haematuria must obviously be related to the history of the patient the age and sex the clinical findings and the results of the laboratory tests Haematuria as a sign has certain definite features it may be solitary intermittent or persistent it may be slight or total it may affect all micturition or only be terminal it may be painless or be associated with dysuria or frequency All these features are significant points in the history taking and can be significant points in directing the radiologist s attention towards relevant aspects of the urinary tract in conducting his examination Part of the *routine* investigation of *all* cases of haematuria is excretion urography irrespective of the age or sex of the patient This examination can provide information about the upper urinary tract that cannot be obtained by any other procedure —the size shape and position of the kidneys and their function in addition it may provide a definite diagnosis with regard to renal pathology the presence of a tumour a chronic pyelonephritis a gross tuberculous lesion a lesion in the renal pelvis or evidence of impaired function or non function of a kidney In addition it may provide useful information about the lower urinary tract—ureteric stasis bladder hypertrophy or dilatation a large bladder tumour bladder diverticula or calculus middle lobe enlargment of the prostate in creased residual urine etc Cystoscopic examination of the patient will inevitably be carried out subsequently which will enable diagnosis of these latter conditions to be made more surely Nevertheless it can be useful to be forewarned of such conditions and to have attention directed to particular features and further information gleaned at

it is carried out immediately after the attack no information is likely to be obtained that will influence the course of treatment and if no demonstration is obtained of the function of the kidney on the affected side it will be necessary to repeat the examination later Whereas if the examination is delayed for a few days it is probable that the calculus or whatever is causing the colic will have been passed and renal function will have had time to recover, thus rendering possible a true record of the state of affairs

(5) Chronic Pyelonephritis

Recurrent urinary infection is sometimes the result of an unsuspected chronic pyelonephritis Also hypertension may be the result of bilateral

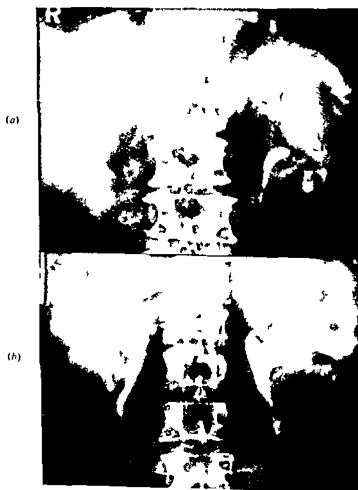


Fig 56 (a) Bilateral pyelonephritis demonstrated by excretion urography (b) Excretion urogram showing chronic pyelonephritis of the right kidney which is contracted has dilatation of its minor calyces and distortion and narrowing of its major calyces

Similarly the passage of a calculus down the ureter can be observed and the development of any obstructive changes noted



FIG 55 Excretion urography eight days after an attack of right-sided ureteric colic The left kidney is normal The right kidney shows as a nephrogram or white kidney There was a small calculus at the lower end of the right ureter which was subsequently passed A follow up pyelogram showed that the kidney had returned to normal

The calculi most easily missed are ureteric calculi especially small calculi in the lower part or intra mural part of the ureter A useful radiological sign when it occurs is the appearance of a nephrogram on the affected side the so-called white kidney while the other side remains functioning normally (see Fig 55) This implies acute ureteric obstruction usually due to impaction of a calculus in the ureter and is caused by the damming back of the contrast medium in the renal capillaries When therefore a unilateral nephrogram is seen during excretion urography search must be made for the ureteric calculus until it is discovered

Often acute renal colic may be caused by minute calculi or crystals or by passage of small clots—none of which will be demonstrated on the radiograph Furthermore severe renal colic often impairs renal function considerably or even suppresses it Excretion urography therefore serves little purpose in the period immediately after an attack In doubtful cases plain X ray examination of the urinary tract may sometimes be helpful in demonstrating a ureteric calculus and thus confirming the cause of the colic as being in the urinary tract But it is wiser to delay excretion urography until 5-7 days after the attack if



FIG 57 (a) Excretion urogram showing right hydronephrosis (b) Prone film taken immediately after (a) showing the grossly dilated renal pelvis and the upper ureter of normal calibre

or unilateral renal disease and in the latter case treatment by nephrec tomy is sometimes successful The investigation of hypertension in the younger age group nowadays invariably includes investigation of the urinary tract by excretion urography The radiological appearances of chronic pyelonephritis therefore are of some importance and are not sufficiently well recognized (see Fig 56)

They are as follows

(*a*) Asymmetrical concentration by the kidneys on the film taken 5 min after intravenous injection of the contrast medium, the patho logical kidney may show slightly impaired concentration at this stage This film should be taken before compression is applied to the abdomen

(*b*) The demonstration of a contracted kidney In most individuals the two kidneys are practically identical in size In chronic pyelone phritis the affected kidney is often contracted

(*c*) Diminished renal parenchyma In good urographs the distance from the outer border of the kidney to an arc drawn through the tips of the minor calyces can be measured this distance represents renal parenchyma and is usually equal in the two kidneys In chronic pyelonephritis this distance may be diminished

(*d*) Loss of the normal cup shape of the minor calyces which become rounded and blunt

(*e*) Elongation and narrowing of the minor and major calyces This distortion of the normal calyceal pattern is quite characteristic of chronic pyelonephritis and is due to fibrosis with scarring within the renal substance

(*f*) The presence of calculi Often some small calculi are present in the minor calyces of the affected kidney

All the changes described are not present in all cases of chronic pyelonephritis Similarly no single one of the appearances described is diagnostic of the condition but the presence of two or more is highly suggestive of it

(6) Hydronephrosis

As seen radiologically renal calyces are normally cup shaped Occasionally one or more calyces may appear en face instead of in profile and so seem to have a round contour—recognition of these rarely presents any difficulty The renal pelvis is usually horn shaped or trumpet shaped and its under surface arched upwards Anatomical variations however are numerous and some renal pelves may appear almost rectangular and in mobile kidneys the under surface of the pelvis may have a downwards curve without this being of pathological significance Where the ureter crosses the psoas it often alters its direction and this may be shown on the radiograph as an apparent kink or narrowing without it being either real or of pathological significance

sufficient pool of contrast medium lies in the dilated calyces This has the effect of allowing the contrast medium to flow forward into the renal pelvis and upper ureter and so providing an adequate anatomical demonstration (see Fig 57 and Fig 58)

(7) Tuberculosis of the Urinary Tract

This condition is always due to a tuberculous bacteriaemia and the first urinary organ to be affected is the kidney the condition is almost invariably bilateral though it may only progress to clinical proportions in one kidney The site involved in the first instance is the glomerulus that is to say the primary lesion in the kidney is in the cortex Histologically the tubercle arising near the arteriole in close association with the glomerulus is the same as a tubercle in any other tissue in the body Tubercle bacilli from this tubercle may spread from the glomerulus and reach the pyramid setting up the same process here From either of these foci tubercle bacilli may be excreted in the urine As in any site the tubercle may develop in various ways depending on the resistance of the host It may heal by fibrosis or cavitate coalescing with adjacent lesions to create large ulcerative lesions From the kidneys the ureters and bladder usually become affected Radiological appearances depend on the site and extent of the disease and may even be absent in relatively advanced disease It has already been stated that radiological appearances are merely graphic representation of gross macroscopic pathology and nowhere does that apply more than in this condition It is important therefore to have a quite clear conception of the role and scope of radiology in this disease Radiologically it is possible to demonstrate either by the excretion or retrograde methods the renal calyces and pelvis the ureters and the bladder The renal outlines are in most cases shown as a definite but barely perceptible line of contrast due to the perinephric fat The space between the renal outline and the calyces is renal parenchyma but it is not possible to see detail in renal parenchyma by either either of these methods Thus tuberculosis of the kidney can only be demonstrated by conventional methods when it has reached the calyx or passed beyond *It is possible to demonstrate* a cavity connecting with a calyx (see Fig 59) A lesion of some long standing around which fibrosis has occurred may show merely as the nipping off of a calyx there may or may not be calcification in association with this Similar nipping off of a calyx not necessarily due to fibrosis may be produced by a granulomatous mass of tuberculosis tissue a tuberculoma Fibrosis or granulomatous masses may produce obstructive effects not amounting to complete obliteration and so a single calyx may become dilated or a whole renal pelvis with all its calyces may become dilated

The distal end of the ureter often becomes affected probably usually by tuberculous infected urine reaching it The ureter then becomes

Hydronephrosis is in most cases due to obstruction. The obstruction may be at the pelvi-ureteric junction, in the ureter, at the ureteric orifice, at the bladder neck or in the urethra. The first effect of the obstructing mechanism is usually shown by the calyces, which lose their cup shape and become blunted, and then dilated. As they dilate, the pelvis may in turn become dilated, and subsequently also the ureter if the obstruction is lower down. As dilatation proceeds, renal function becomes impaired, and concentration of the contrast medium at excretion urography becomes less good. The excreted contrast medium therefore may pool in the dilated calyces on the affected side and no satisfactory demonstration of the renal pelvis and ureter be obtained.

It is essential for the surgeon to know at what level the obstruction lies, and above all to be able to visualize the pelvi-ureteric junction and upper ureter. If the renal calyces and pelvis are dilated, but the upper ureter of normal calibre, then the obstruction lies at the pelvi-ureteric junction, but if the upper ureter is also dilated then the obstruction lies beyond.

It is routine procedure now for most radiologists when conducting this examination, on seeing a hydronephrosis, to have a film taken in the prone position, near the close of the investigation when adequate demonstration of the other kidney has been obtained and when a



FIG. 58. (a) Excretion urogram showing left hydronephrosis. (b) Prone film taken immediately after (a) showing [illegible] dilated calyces and [illegible] a marked hydro[illegible]

(i) Urinary tuberculosis will occasionally be revealed when it has not been suspected clinically

(ii) In suspected cases urography may appear normal The surgeon must not be misled by such findings and cases presenting with symp toms a sterile pyuria and normal urography require further investiga tion such as bacteriological examination segregation of urine from the ureters etc

(iii) In certain suspected cases definite radiological signs may be found These give some gross idea of the macroscopic extent of the disease

(iv) Serial X ray examination of cases undergoing conservative treatment may provide some indication of the progress of the disease

(v) Serial X ray examination of cases undergoing conservative treatment may provide early indication of untoward side effects of the treatment such as local obstruction

(vi) Urinary tuberculosis is commonly associated with tuberculosis of another system usually either pulmonary or bone tuberculosis and radiological methods will often reveal the site extent and course of such a complication

(8) Renal Tumours

Some renal tumours reach considerable size before producing any symptoms or signs others causing a brisk haematuria may subsequently be found to be no bigger than a walnut

On the plain film the appearances which give rise to the suspicion of a renal tumour are deformity enlargement or displacement of the renal outline or occasionally speckled intra renal calcification On excretion urography the principal radiographic features are obliteration of calyces elongation with either compression or dilatation of calyces displacement of calyces obliteration or dilatation of the renal pelvis displacement of the pelvis and upper third of the ureter or non filling of the calyces and pelvis

The differential diagnosis of a space occupying lesion in the kidney is often not possible from excretion urographs and any attempt on the part of the radiologist to give emphasis either to a diagnosis of solitary cyst or renal carcinoma may be misleading and not in the best interests of the patient Nevertheless cases arise when the surgeon would prefer not to embark on an exploratory operation if the space occupy ing lesion is a solitary cyst for example in the routine pre operative examination of a case of prostatism excretion urography may bring to light a silent renal tumour the surgeon may be unwilling to submit an elderly patient to further surgery if the diagnosis is not established as being renal carcinoma

Renal arteriography with serial films of the kidney taken during the

obstructed or partially obstructed and rising involvement of the ureter occurs The ureter becomes thickened and dilated fibrotic and shor tened showing radiologically as a typical short straight dilated struc ture In due course the bladder becomes affected it becomes thickened round and contracted All these features may be shown radiologically



FIG 59 Excretion urogram in a case of sterile pyruria The uppermost of the middle group of calyces in the left kidney has been replaced by a tuberculous cavity connecting with it

The modern treatment of tuberculosis of the urinary tract whether by anti tuberculous drugs or surgery or a combination of both has probably not yet settled into its final form Nevertheless conservative treatment has undoubtedly a definite place The main danger of con servative treatment is the development of fibrosis and so of obstructive effects Such effects can nullify the whole aim and end result of the treatment Serial X ray examination at about intervals of three or four months during treatment can bring to light the development of obstructive effects and so allow surgical interference

The role of radiology in this disease may be summarized as follows

(iii) A needle is introduced from the back so as to enter the kidney in the region of the suspected lesion and is aimed under screen control towards the tumour

(iv) If the needle enters a cyst straw coloured fluid is aspirated whereas in the case of a neoplasm blood is aspirated

(v) Two or 3 ml of contrast medium are then injected into the lesion In the case of a cyst the cavity is outlined and its size can be compared with the original urograph In the case of a neoplasm the

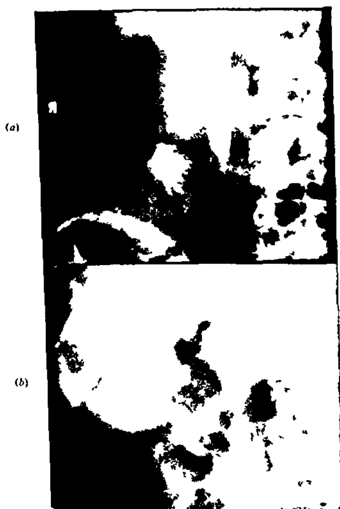


FIG 61 (a) Renal puncture in a case of carcinoma of the kidney showing the injected contrast medium tracking irregularly in the tumour Excreted contrast medium from the preliminary intravenous injection can be seen in the renal pelvis (b) Renal puncture in a case of renal cyst showing the smooth round shape of the cyst wall

contrast medium is shown to track irregularly within the tissue (see Fig 61)

arterial capillary and venous phases will usually establish the diagnosis By this method tumours such as adeno carcinoma show a mottled pooling of the contrast medium within the substance of the space occupying lesion which persists into the capillary and venous phases (see Fig 60) A space occupying lesion which however is due to a renal



FIG 60 Aortogram done by direct aortic puncture in a case of right renal mass shown at excretion urography The left renal artery and its branches are shown to be normal The right renal artery is normal but the branches to the mid part and lower pole of the kidney have been replaced by a plexiform mass of vessels confirming a diagnosis of carcinoma of the kidney

cyst is avascular and shows as a defect in the capillary or nephrogram phase To carry out this procedure a simpler technique requiring no special apparatus for differentiating between growth and renal cyst in such cases is the procedure of renal puncture which can be carried out as follows

(i) An intravenous injection of 20 ml of contrast medium is made in order to produce a pyelogram

(ii) A metal marker graduated in centimetres is put on the patient s skin and lateral and postero anterior films are taken From these the exact site and depth of the kidney and its space occupying lesion can be estimated accurately

Similarly growth diverticulum or stone in the bladder the classical complications of an enlarged prostate may be demonstrated radio logically and often require treatment as a staged procedure before the prostate It is true that all these things are visible with the cystoscope but it is not desirable to perform cystoscopy in the presence of a very



FIG 6? Cystogram 30 min after injection in excretion urography showing hypertrophy of the wall as a ring shadow outsid the filled cavity of the bladder

enlarged prostate before the actual time of operation for fear of in ducing acute retention and it is not possible to assess the size of a diverticulum with the cystoscope The bladder demonstration dur ing excretion urography will almost always demonstrate stone or diverticulum and will often demonstrate the presence of a large growth

(*e*) *Bladder Function* The presence of residual urine after micturition can be demonstrated by this method and a fair assessment of its amount can be made This eliminates the need for instrumentation

(*f*) *Prostate Anatomy* Rectal examination reveals lateral lobe enlargement if middle lobe enlargement exists the information derived from rectal examination can be supplemented by the demonstration of its mid line intravesical projection as a filling defect in the cystogram (see Fig 63) Similarly the presence of prostatic calculi can be shown

This technique obviously has a limited application and it is likely that in many cases surgeons will prefer to undertake exploration Nevertheless occasions will arise when the procedure can usefully be employed and it has come to take its place in the full array of radio logical investigations

(9) Prostatic Hypertrophy

In all patients complaining of symptoms due to an enlarged prostate with the exception of those in whom a severe degree of renal failure makes the examination useless excretion urography forms part of the routine investigation in assessing them In assessing such patients clinical examination reveals only the gross abnormality whereas it is necessary to be able to detect early and less obvious changes The information which can be provided by this radiological method is a refinement of the ordinary methods of clinical examination of the urinary tract and may be considered as follows

(*a*) *Renal Anatomy* Before dealing surgically with the lower urinary tract the surgeon requires to know that he is dealing with a normal upper urinary tract He wants to know that both kidneys are present that they are not hydronephrotic and that they do not harbour an alternative cause for haematuria such as a stone or growth in a man with prostatic enlargement

(*b*) *Renal Function* It is important to know that both kidneys are excreting and concentrating well Although laboratory tests may show the blood urea level to be raised they give no indication of its cause which may be due to chronic pyelonephritis or to hydronephrosis from back pressure If the blood urea level is above 120 mg per cent it is unlikely that concentration of diodone will occur but up to that level often useful information regarding the kidneys can be obtained It is useful to know whether a hydronephrosis exists which may be expected to improve after adequate drainage or a pyelonephritis indicating renal failure without obstructive dilatation which will not recover under any circumstances Excretion urography too gives a good visual record of improvement following drainage

(*c*) *Ureteric Function* Stasis in the lower end of the ureters or persistent filling of the whole length of both ureters in the presence of good excretion usually occurs with a significant amount of residual urine in the bladder and is a warning that the beginnings of renal failure are imminent

(*d*) *Bladder Anatomy* A thick walled bladder results from long continued obstruction and occurs often with gross trabeculation and saccule formation (see Fig 62) Its demonstration eliminates the possibility of an atonic or paralytic bladder and warns of the possibility of infective complications following operation due to stagnant blood and urine in deep saccules

and the knowledge of their presence may be of help in deciding whether or not a hard area in the prostate is malignant

Finally in carcinoma of the prostate the demonstration of osteo blastic skeletal metastases may establish the diagnosis when the serum acid phosphatase estimation is unhelpful and the course of such meta stases can be observed graphically under treatment (see Fig 64)

FIG 63 Cystogram 30 min after injection in excretion urography showing a sacculated bladder and a large intravesical projection of the middle lobe of the prostate

FIG 64 Osteoblastic metastases from carcinoma of the prostate affecting the right side of the pelvis

process then the diagnosis lies elsewhere and it would be wise to undertake bone biopsy

(*b*) *Osteitis of a Phalanx* In the presence of an acute or chronic paronychia or cellulitis of a finger the question may arise whether or not there is bone infection or necrosis When the bone is infected it becomes intensely hyperaemic hyperaemia of bone always produces an osteoporosis So the affected phalanx becomes extremely osteoporotic the bony trabeculae in it may be absorbed and be no longer visible the bone remaining apparently merely as a faint shell of cortex Osteoporosis of such a degree is not an indication of bone necrosis but merely of inflammation If treatment is successful a phalanx involved even to this extent can undergo repair and complete bony re constitution can take place The only radiological indication of necrosis of part of a phalanx is when that part separates and by contrast appears denser than the parent fragment this is an indication that it is avascular and has been sequestrated

The other valuable feature of X ray examination of digital osteitis is the demonstration of whether or not the adjacent interphalangeal joint is involved When the joint becomes affected articular cartilage is destroyed and the joint space becomes narrower than the corresponding

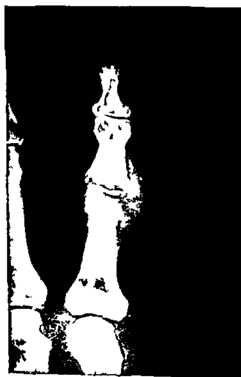


FIG 65 Osteitis affecting the proximal and middle phalanges of the 5th digit with inflammatory destruction of the intervening joint

CHAPTER 7

BONE

WITH the great specialization that has taken place within the broad realms of surgery most bone and joint diseases have tended to become the prerogative of the orthopaedic surgeon Nevertheless in routine practice in general surgery the practising surgeon is faced with many problems in which bone pathology is an important element The radiological aspects of several of these are discussed here

(1) Inflammatory Conditions

(*a*) *Osteomyelitis* Acute osteomyelitis is usually diagnosed and treated before radiological signs develop as it takes at least 7 days and sometimes more before bone changes appear Antibiotic therapy is now so effective that it is not uncommon for a case of acute osteomyelitis to be admitted to hospital treated and discharged without there being any radiological evidence whatsoever of bone disease

Sometimes however bizarre and uncommon pictures present when antibiotic therapy has been inadequate Occasionally such cases *present many weeks or months later with a constant limb pain but* no very definite localizing signs this type of case is usually one that has not reached hospital in the first instance and whose acute infection was dealt with by domiciliary treatment

Often the radiological appearance in such cases is merely of a cortical thickening along part of the shaft of the affected bone This cortical thickening may be only slight or markedly proliferative and it may even have layered new periosteal bone on its surface Because of the clinical presentation the clinical signs and the unusual radiological appearance the differential diagnosis is difficult the possibility of malignant conditions such as reticulo sarcoma Ewing s tumour and metastatic neuroblastoma must be considered and obviously early diagnosis is important for treatment differs There are no radiological signs which per se divorced from the history and clinical course are diagnostic As a generalization it can be said that in local osteoperiostitis of the type being discussed the cortical thickening is usually dense medullary changes are rare layered periosteal new bone is rare and the condition is usually not progressive If there is destruction of medullary bone with formation of new periosteal bone and the condition is shown over a short period of observation to be progressive all in the absence of clinical signs consistent with an acute inflammatory

process then the diagnosis lies elsewhere and it would be wise to undertake bone biopsy

(*b*) *Osteitis of a Phalanx* In the presence of an acute or chronic paronychia or cellulitis of a finger the question may arise whether or not there is bone infection or necrosis When the bone is infected it becomes intensely hyperaemic hyperaemia of bone always produces an osteoporosis So the affected phalanx becomes extremely osteoporotic the bony trabeculae in it may be absorbed and be no longer visible the bone remaining apparently merely as a faint shell of cortex Osteoporosis of such a degree is not an indication of bone necrosis but merely of inflammation If treatment is successful a phalanx involved even to this extent can undergo repair and complete bony re constitution can take place The only radiological indication of necrosis of part of a phalanx is when that part separates and by contrast appears denser than the parent fragment this is an indication that it is avascular and has been sequestrated

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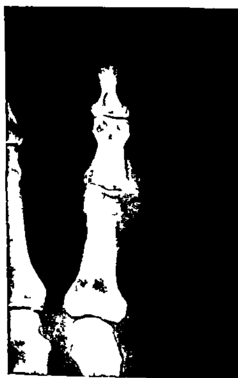
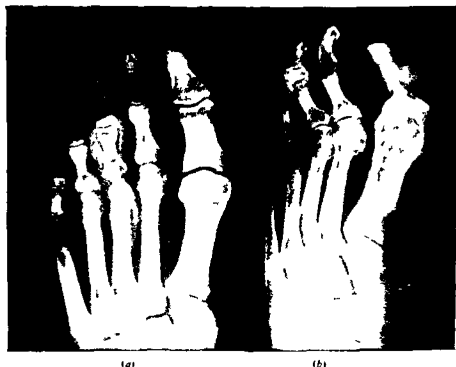


FIG 65 Osteitis affecting the proximal and middle phalanges of the 5th digit with inflammatory destruction of the intervening joint

joint of the next finger (see Fig 65) In addition sometimes a break or defect can actually be seen in the sub-articular bony cortex Knowledge of the state of the joint clinches the surgeon s prognosis and may influence his course of treatment

(c) *Bone Changes in Diabetes* The bone and joint changes that occur in diabetes notably in the feet had long been regarded as Charcot s joints due to diabetic neuropathy It is now known however that these changes are predominantly inflammatory and not neuropathic though in gross cases of diabetic neuropathy there may be neurological factors complicating the process This is of considerable importance for of course the inflammatory process can be arrested at any stage by controlled antibiotic and anti-diabetic treatment thereby allowing surgical toilet of the condition and the retention of what appears to be a hopelessly damaged foot.



(a) (b)

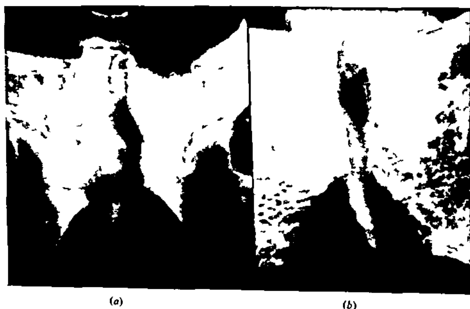
Fig 65 *(a) Inflammatory changes producing osteoporosis, bone destruction and a periosteal reaction around the third metatarso-phalangeal joint in a diabetic with an ulcer on the sole of the foot* *(b) Tapering of the proximal phalanx and destruction of the interphalangeal joint of the great toe in a diabetic with a history of repeated cellulitis of the foot There was no clinical evidence of neuropathy*

The process is as follows An acute or low grade infection begins near the bone often near the weight bearing metatarso-phalangeal joints The port of entry may be a perforating ulcer a septic corn or diabetic cutaneous gangrene Superficial lesions may heal well but

deep sepsis can still persist tracking along the periosteum Radiologically a local osteoporosis develops Soon a break occurs in the cortex and an osteitis ensues At this stage there is often a periosteal reaction along the involved metatarsal (see Fig 66 (*a*)) this proceeds to progressive destruction of the head of the bone then of the medulla of the adjacent shaft The cortical walls approximate producing a tapering appearance (see Fig 66 (*b*)) The process may be arrested at any stage or may progress to very gross destruction Repeated weight bearing on the denervated foot does not help repair nor does the poor blood supply which is a frequent accompaniment

(*d*) *Osteitis Pubis* Occasionally after either retro pubic or suprapubic prostatectomy this painful condition arises The symptoms may start anything from two weeks to three months after operation It may cause pain in the perineum or over the ischial tuberosities pain referred down the thighs or even down the legs or pain on micturition or defaecation Signs are usually few or absent though in some cases there is pain on pressure over the symphysis pubis

Radiologically it manifests itself as a loss of cortex on one or both sides of the symphysis pubis followed by an osteoporosis of sub-cortical bone (see Fig 67) This is followed by a sclerotic reaction in



(*a*) (*b*)

FIG 67 (*a*) Osteitis pubis affecting both sides of the symphysis Film taken four months after retro pubic prostatectomy (*b*) Osteitis pubis causing at this stage only loss of cortex along the left side of the symphysis Ten weeks after retro pubic prostatectomy

sub-cortical bone and dense re ossification of the area of affected bone sometimes leading to complete bony fusion across the symphysis

The clinical condition rarely responds to specific therapy and it may

take twelve months to settle The radiological course of the condition usually takes 12–18 months before final bony consolidation is established

(*e*) *Bone and Joint Tuberculosis* The prognosis in cases of bone and joint tuberculosis has altered radically in recent years with the introduction of modern therapy It is ever more important that diagnosis should be made early so that treatment can be started at the earliest possible opportunity The radiology of chronic bone disease lags far behind both the clinical condition and the pathological state The diagnosis therefore is often a clinical one backed by laboratory tests with radiological investigation being equivocal The radiological picture will usually show the gross macroscopic extent of the destructive process but will not show the minor detail in early disease

Tuberculosis of a joint is sometimes primarily synovial and sometimes primarily articular In the former cases extensive disease can exist without their being any abnormal radiological signs other than synovial



FIG 68 Tuberculous caries sicca of the shoulder joint There is a large area of destruction in the head of the humerus and a second smaller area lying medially The glenoid fossa is also affected

swelling which is more easily detected at clinical examination When involving bone tuberculosis is a destructive process, destroying all structures in its path and exciting no bone reaction in the nature of adjacent sclerosis If it commences in the metaphysis it may appear as an area of osteoporosis in which no bony trabeculae are visible the overlying cortex may also be destroyed The pathological process may then progressively destroy the adjacent epiphyseal cartilage and bony structure in the epiphysis discharging into the joint cavity affecting synovium and destroying articular cartilage (see Fig 68) In time the adjacent bone forming part of the joint may become affected This destruction will be shown radiologically as local destruction of bone without local bone reaction and with narrowing of the joint space as the articular cartilage is destroyed Sclerosis of bone in this condition only rarely occurs in very chronic cases where the advance of the destructive process has not been rapid and the forces of repair have attempted to seal off the pathological process If however a sinus has discharged on to the skin surface and this has become secondarily infected as is almost inevitable the secondary infection of underlying bone with pyogenic organisms will cause a bone reaction with sclerosis

The role of radiology in this disease therefore is to show the extent of the damage to the affected bone or joint to confirm clinical opinion that progression has been halted and to demonstrate complications such as the involvement of a second bone or secondary infection of bone under a sinus

(2) Aseptic Necrosis of Bone

Necrosis of bone is characterized microscopically by degeneration of the osteocytes Not all parts of the bone are necrotized at the same time Spongy bone and haversian lamellae of compact bone may still be fairly intact containing undamaged osteocytes Peripheral or interstitial lamellae of compact bone are the first to become necrotic these are the older parts of the bone tissue which have already sustained some damage as a result of a decrease in their nutrition prior to the injury which caused the necrosis of bone Radiological diagnosis can only be made of gross anatomical change in the later stages from the reaction of the surrounding tissue

The fate of necrotic bone may differ widely The most important single factor is whether the bone is in contact with living connective tissue The most favourable outcome is its elimination by osteoclastic activity and its gradual replacement by normal living bone

This type of healing is frequent and seems to be nothing more than the extension of the regeneration of bone a process which occurs throughout life

If the connective tissue covering a bony surface has been damaged so

that it loses its vitality the elimination of necrotic bone is still possible by what is called undermining resorption which may start for instance in the bone marrow spaces after damage to the periosteum

During ordinary regeneration of aged bone the resorption is often incomplete at first and the new bone is built upon the surface of the partially resorbed bone The same fate is observed after pathological necrosis of bone After the initial resorption the process is reversed before the necrotic bone is completely eliminated This is a process of walling in or burying the dead bone by increased osteoblastic activity New dense compact bone is formed round the necrotic area

If necrotic bone loses its connection with living reactive connective tissue its elimination is impossible and it becomes a sequestrum

Thus the interplay of osteoclasis and formation of new bone is observed in all these processes If the process of regeneration, resorption and formation of bone proceeds undisturbed complete healing may be observed Mechanical injuries or secondary infection occurring during this period may however lead to permanent deformity

In ischaemic necrosis of bone there is a total necrosis bone tissue and marrow of a bone or part of it

The next stage is repair During resorption young connective tissue invades the involved area and new bone is substituted for necrotic bone Some trabeculae escape resorption and new bone is laid down on their surface At the same time the necrotic marrow is replaced by granulation tissue after the cell debris has been removed by macrophages The necrotic bone during this process is often subjected to spontaneous fracture The articular surface above this bone thus loses the firm support which normal bone gave it and becomes damaged Continued friction between the two fragments of such a spontaneous fracture causes a grinding of necrotic bone and the zone of fracture is soon filled with bone dust which is forced into the neighbouring bone plugging the narrow spaces One part of necrotic bone is thus separated by a barrier from the other part This barrier presents great resistance to *regeneration of the peripheral part*

This demarcated area may eventually undergo regeneration or it may remain demarcated

Radiology in this condition as always is merely a graphic representation of the pathological process In childhood the commonly affected sites are certain ossific centres e g the head of the femur (Perthes disease) the tarsal navicular (Kohler s disease) the head of the second metatarsal etc The etiology of the condition is usually unknown though trauma may occasionally be incriminated but whatever the etiology the pathology is as described above At the outset there are no radiological changes but as multiple spontaneous fractures occur and weight bearing continues the affected bone becomes compressed and denser and more sclerotic This appears radiologically as a minor

variation and irregularity in shape and an increased density (see Fig 69) The forces of repair then bring about a hyperaemia of the adjacent healthy bone hyperaemia of bone always causes osteoporosis and this osteoporosis increases by contrast the appearance of sclerosis of the necrotic bone In time if further weight bearing is not prevented considerable deformity and flattening of the necrotic bone may take place As resorption of the necrotic bone occurs small zones of lesser



FIG 69 Perthes disease of the left hip The femoral head is fragmented compressed and denser than its fellow in the right hip As yet no radiological evidence of repair is shown

density are seen in the sclerotic area and in time new bony trabeculae of normal density are laid down in the now deformed matrix In childhood it is common for all the necrotic bone to be resorbed and replaced though the whole process may take two or even three years

In the adult the zones of necrosis are usually more confined and circumscript They are often sub articular and affect a segment of an articular surface Or the whole of a narrow strip of the sub articular zone of an articular surface may be involved the bone deep to this not being affected in the initial process but only in the process of repair (see Fig 70) If a wedge shaped segment of bone in an adult becomes necrotic it is rare for all the necrotic bone to be absorbed if how ever only a narrow strip is involved it may all be absorbed In the adult the pathological process of repair often produces the more obvious radiological changes hyperaemia produces osteoporosis of the adjacent bone absorption shows as a loss of bony trabeculae possibly proceeding to the formation of cyst like areas reconstitu tion of bone is often minimal the sealing off of the involved area by

the laying down of reactive bone round it shows as a sclerotic ring round the cyst Nature s attempt to alter joint mechanics to relieve the affected area of necrotic joint surface produces osteophytes at the periphery—an osteoarthritis

The processes here described have found their way into the literature on bone pathology under many titles such as osteochondritis epiphysitis etc it is better however to refer to them by a name which



FIG 70 Avascular necrosis in the femoral head of an adult male aged 6 The necrotic zone of bone can be seen separated from the remainder of the bone by a line of demarcation. It has been compressed into the area of repair producing a "step" on the articular surface

describes the pathological process whatever the etiology namely avascular necrosis The radiological picture is a portrayal of the state of affairs at a point in time either of the development of the condition or of the repair process or of the complications which ensue

(3) The Spine

(a) Inter vertebral Discs The syndromes due to posterior herniation of intervertebral discs which may commonly occur in the lumbar and cervical regions less commonly in the thoracic are well known It is less well realized that plain radiography of the spine has little part to play in the diagnosis of the condition though it has an essential part to play in the investigation of suspected cases

An intervertebral disc consists of the central nucleus pulposus round

which is the annulus fibrosis The outer layers of the annulus fibrosis are continuous with the connective tissue which forms the periosteum over the surface of the adjacent vertebral bodies Either due to age or repeated minor trauma or strain the nucleus pulposus may become dehydrated and degenerate when this happens it loses its property of resilience or turgescence is less able to stand the up and down thrust of everyday weight bearing and begins to bulge horizontally As the spine is fixed posteriorly by the articulating diarthrodial joints the bulge is more commonly forwards or laterally less commonly backwards As the disc bulges outwards beyond its normal limits the continuous outer layer of connective tissue is elevated from the surfaces of the adjacent vertebral bodies this excites an osteoblastic reaction and bony spurs or osteophytes grow under this elevated periosteum round the outer edge of the bulging annulus fibrosis This condition which is common in persons over the age of 50 years and may be seen at much earlier ages is symptomless and is best referred to as osteo phytosis though the term spondylosis is sometimes used It should be clearly differentiated from osteo arthritis of the spine which affects the posterior diarthrodial joints and is a painful condition Osteophytosis of the spine may affect one or many discs and shows radiologically as a diminished disc space with bony spurs projecting from the edge of the vertebrae around the edge of the disc (see Fig 71)

Posterior herniation of a disc such as may give rise to neurological signs and the clinical state commonly associated with the condition is a totally different picture It may occur in young persons the middle aged or elderly it may be acute or chronic It may occur in a person whose spine shows no previous degenerative changes or in a person whose spine already shows some of the signs described in this section Posterior herniation of the disc can be due to actual splitting of the fibres of the annulus fibrosis with herniation of some of the substance of the nucleus fibrosis through the gap or merely due to posterior bulging of the disc associated with degenerative changes In either case the normal mechanics of the disc become altered and in the course of time probably not less than twelve months the radiological signs of disc degeneration will be shown there is no sure method of differen tiating by plain conventional radiography between a degenerated disc which is merely part of an osteophytosis and one which is a result of posterior herniation Even if there are posterior osteophytes visible radiologically projecting into the spinal canal these may not be associ ated with symptoms In an acute disc herniation there may be no radiological changes whatsoever

Two signs may be seen on the radiograph in posterior disc herniations producing symptoms and signs which though not diagnostic by themselves may add to the general clinical picture and so help to establish a diagnosis There may be loss of the normal lordosis and

the laying down of reactive bone round it shows as a sclerotic ring round the cyst Nature s attempt to alter joint mechanics to relieve the affected area of necrotic joint surface produces osteophytes at the periphery—an osteoarthritis

The processes here described have found their way into the literature on bone pathology under many titles such as osteochondritis epiphysitis etc it is better however to refer to them by a name which



Fig 70 Avascular necrosis in the femoral head of an adult male aged 56 The necrotic zone of bone can be seen separated from the remainder of the bone by a line of demarcation It has been compressed into the area of repair producing a step on the articular surface

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this can occur in either the lumbar or cervical regions And there may be alteration in the width either an increase or a decrease of the *posterior* end of the disc compared with the adjacent discs above and below However the real role of radiology in this sphere is to exclude other pathology as a cause of the symptoms and signs under investigation and no case of clinically diagnosed herniated disc should ever be regarded as completely investigated until this procedure has been carried out

Cases are encountered in which the clinical diagnosis despite full clinical examination is not clear or in which the signs elicited do not permit exact localization of the level of the herniation In such cases two further radiological procedures are available as an aid to diagnosis Both procedures require to be carried out in the X ray department using first-class high output apparatus in the hands of an experienced radiologist

Myelography is the technique by which 2 or 3 ml of opaque medium are injected into the theca The two satisfactory media in common use are Pantopaque and Myodil Then under screen control the patient is tilted into the head down or feet down position and the medium thus made to run up and down within the theca The examination is carried out in both supine and prone positions and so the whole region in question can be investigated Films are taken during the procedure as required and in this type of case it is always essential to have lateral films of the area in question taken with a horizontal X ray beam so as to have the opaque medium actually resting on the posterior borders of the discs under investigation

Disc puncture and injection (discography) is the technique whereby an opaque medium is injected into the nucleus pulposus For examination of the lower lumbar discs the patient lies on his side on the X ray table with his knees well up and his back arched A guide wide bore needle is then passed in the mid line between the spinous processes towards the disc under examination in a direction selected from a preliminary film A long needle (5) and stilette are then passed through the guide *needle through the annulus fibrosis into the disc If the point* of the needle impinges on bone it is withdrawn slightly its direction adjusted and then re inserted A check film at any stage will confirm the correctness of the direction When the needle is in the disc 35 per cent diodone is injected 0 5 ml to 1 ml can be injected with difficulty into a normal disc 1 5 ml will go relatively easily into a degenerated disc The needle is then withdrawn and lateral and anterio posterior films taken followed by an erect lateral film The contrast medium is absorbed from a normal disc in little more than hour but traces of it may remain in a degenerated disc for up to 24 hr In a normal disc the nucleus pulposus is seen to be an oval shape with a wide band round it which does not fill with contrast medium—the annulus fibrosis



FIG 71 Osteophytosis of the lumbar spine

The role of radiology in scoliosis is

(i) to demonstrate any vertebral anomalies or by excluding them to exclude congenital scoliosis

(ii) to act as a record of the angle of the primary curve and so by comparison with subsequent examinations to show whether the curve is progressing or whether correction is being maintained

(iii) to demonstrate in cases of idiopathic scoliosis whether or not the compensatory curves above and below the primary curve will straighten out

The technique is to take

(i) a straight antero posterior view of the affected part of the spine on one film with the patient standing erect

(ii) an antero posterior view of the same area with the patient standing and flexing his spine to the left side

(iii) the same as (ii) with lateral flexion of the spine to the right side

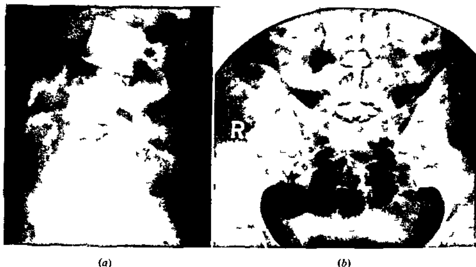
(i) is carried out at three to six monthly intervals during con servative treatment (ii) and (iii) are only carried out at the first examina tion and again prior to surgical correction and fusion if this is under taken

The angle of the primary curve is measured on the film taken on (i) above and is actually marked on the film The upper and lower vertebrae of a primary curve show no rotation of the spinous process and the discs above and below them are not wedged From the upper and lower borders of these vertebrae respectively perpendiculars are drawn and the angle at which these meet is the angle of curvature

(c) *General Principles of Investigation and Interpretation* Radio logical interpretation of diseases of the spine is not always a simple matter especially when the disease process though sufficiently advanced to produce symptoms and signs is still in a relatively early stage and bone and joint changes are minimal In the thoracic spine the overlying shadows of ribs and lungs may cause confusion in the cervical region the super imposition of the shadows of the transverse processes and articular facets cause difficulty and in the lumbar spine the projection of bowel shadows over the vertebrae render interpretation difficult Routine radiographic procedures will usually overcome these difficulties but if doubt still lingers regarding the state of the spine after thorough scanning of the conventional films or if for permanent record it is required to have an accurate demonstration of the state of a patho logical process tomography of the spine will provide the answer This is a precision technique and is time consuming but a minute dissection of the spine can be carried out by this method

For example if a child in the 10-15 years age group is complaining of an ache in the back and clinical examination reveals a kyphosis limitation of movement and tenderness over the lower thoracic spine the possibility of tuberculosis of the spine arises X ray examination

(see Fig 72) In a degenerated disc the annulus fibrosis is seen to be narrower and possibly bulging the contrast medium is seen to spread more and may be shown actually to track into a herniated portion



(a) (b)

Fig 72 (a) Discography Opaque medium has been injected into the disc between the bodies of L V 4 and 5 which is shown to be normal Opaque medium has also been injected into the lumbo sacro disc and is shown to track further in this degenerative disc (b) A P projection of the case shown in (a) The fragmentary tracking of the opaque medium in the lower disc is better shown

(b) *Scoliosis* Scoliosis may be congenital idiopathic neuropathic myopathic or thoracogenic The thoracogenic scolioses following empyema pneumonectomy or thoracoplasty are rare nowadays and the myopathies such as muscular dystrophy do not produce a progressive scoliosis

Neuropathic scoliosis as a result of poliomyelitis depends on the muscle groups affected The most important prognostic factor is the age at which the disease first affected the child Most paralytic scolioses develop within two years of the disease and the earlier the age of onset the longer the imbalance of muscle has to affect vertebral growth and the greater is the final distorting curvature

Congenital scolioses are associated with demonstrable vertebral anomalies such as hemi vertebrae congenital absence of discs and fusion of vertebral bodies absence of ribs rib fusions etc

Probably the most important single group are the idiopathic scolioses The primary curve may be thoracic thoraco lumbar lumbar or combined thoracic and lumbar all with compensatory curves above and below Idiopathic scoliosis is progressive as long as vertebral growth takes place but does not progress after cessation of growth and the higher in the spine is the primary curve the worse is the prognosis

Treatment may be conservative or by surgical correction and fusion

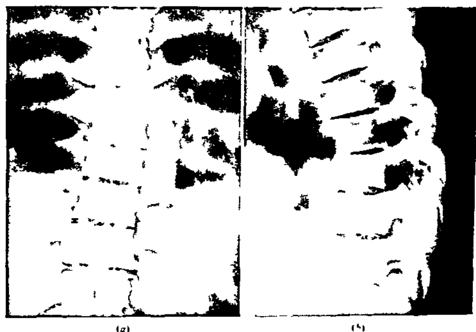
(a) (b)

FIG 74 (*a*) and (*b*) Tomographs of mid thoracic spine in a case of juvenil osteochondritis showing herniation of the nucl us pulposus into a vertebral body narrowing of th relevant disc but no increase in the width of the paravertebral shadow



FIG 75 Radiograph of the lumbar spine showing a d fect in the pars interarticularis of a vertebra—spondylolysis

of the spine may reveal deformity of the lower thoracic vertebral bodies with narrowing of the intervertebral spaces However juvenile osteochondritis (or epiphysitis) of the spine can produce a similar clinical and radiological picture The treatment and prognosis differ widely and accurate diagnosis is essential Tomography of the spine will reveal the true nature of the condition Tuberculosis is a destructive process often involving the opposing surfaces of adjacent vertebral bodies producing in the early stages no bony reaction or sclerosis the edge of the destructive lesion in bone is ill defined the intervening disc space narrows due to destruction of its substance and early there develops a paravertebral abscess producing widening of the para vertebral shadow in the thoracic region or a psoas bulge in the lumbar region (see Fig 73) O teochondritis is due to interference with the



(a) (b)

FIG 73 (a) and (b) Antero-posterior and lateral tomographs of the mid thoracic spine in a case of tuberculosis showing caries in adjacent vertebral bodies, destruction of the intervening disc and a wide para vertebral shadow

blood supply to the cartilaginous end plate which necroses breaks and allows the nucleus pulposus to herniate through the break into the spongiosa of the vertebral body there is an immediate bone reaction producing a sclerotic ring of bone sealing off the herniation Interference with growth of the vertebral body occurs with increased growth in an antero-posterior direction a temporary cessation of vertical growth producing a wedge shaped vertebra There is never any increase in the para vertebral shadow or psoas bulge in this condition (see Fig 74)



FIG 76 Paget's disease of the femur showing the recent fibrotic replacement of normal bone at the upper margin reossification in the middle of the affected part and dense reossification at the lower end One of the complications of Paget's disease a horizontal fracture is shown united in the mid shaft

Similarly tomography will help to elucidate other conditions of the spine such as anomalies and injuries in the atlanto axial region injuries to any region of the spine, primary tumours such as osteo clastoma or metastatic spread diastomatomyelia neurofibromata etc

On the other hand routine conventional radiography is usually eminently satisfactory for the demonstration of such conditions as haemangioma (the large venous plexus of which may be the cause of severe symptoms and signs) spondylolysis (see Fig 75) spondylolisthesis osteo arthritis of the diarthrodial joints spondylosis and the exclusion of other pathology in cases of suspected posterior disc herniation

(5) Paget's Disease

This condition alternatively known as osteitis deformans or osteitis hyperplastica is of unknown etiology If it becomes clinically manifest it is usually in the older age groups though it may often commence between the ages of 35 and 45 years It affects both sexes but is commoner in males It affects predominantly the Caucasian races and the writer has not seen a proven case in an African It is often symptom less but can cause bone pain or vague aches Clinical presentation is usually due to the complications of the disease rather than to the con dition itself Any bone can be affected but the pelvis spine skull femur and tibia are the commonest The condition causes enlargement of the affected bone and bending of the bone may take place during the fibrous stage The enlargement of bone may produce mechanical effects such as impairment of joint movement leading to osteo arthritis of that joint or neurological signs due to narrowing of the basal foramina of the skull During the fibrous stage the bone is very vascular and if many bones are affected they may act as a large reservoir of blood putting an added strain on the cardio vascular system Pathological fractures through affected areas are not uncommon Sarcoma may arise in affected bones and osteogenic sarcoma arising in pre existing Paget s disease *is the commonest form of bone sarcoma in the older age groups* it is usually predominantly osteolytic with little or no osteoblastic reaction In these circumstances it can be difficult to differentiate between this and metastatic carcinoma occurring in Paget s disease

The disease may affect one or many bones and in any one bone it may arise in one site and extend or be multi centric The process consists of osteoclastic resorption of normal bone and its replacement with an exuberant fibrous marrow which in turn slowly re ossifies The re ossification however takes place in an abnormal pattern and has a characteristic histological appearance described as having a mosaic pattern It is during the stage of fibrous replacement that expansion takes place and deformities may occur The fibrosis may be extensive with re ossification lagging well behind or each small area of fibrosis



FIG 76 Paget s disease of the femur showing the recent fibrotic replacement of normal bone at the upper margin reossification in the middle of the affected part and dense reossification at the lower end One of the complications of Paget s disease a horizontal fracture is shown united in the mid shaft

may ossify relatively quickly The radiological appearances depend on the type of pathological pattern which the process has adopted The process often affects the cortex initially and the advancing edge of fibrosis appears like an osteoporotic arrowhead splitting the cortex This osteoporotic zone of fibrosis may be quite extensive but if re ossification does not take place early thick coarse bony trabeculae may be seen an inch or possibly two inches away from the advancing edge As re ossification proceeds dense sclerotic new bone is laid down in the form of these thick coarse trabeculae (see Fig 76) If however at the outset the involvement of bone is multicentric and extensive re ossification may proceed rapidly following the stage of fibrosis so no true advancing edge of fibrosis can be detected radiologically the whole merely having the appearance of normal bone being replaced by thick abnormal bony trabeculae with wide inter trabecular spaces The speed of advance of the process is variable and in any one site the condition may go into remission for periods of years only to recommence at a later date During the active phase which may persist for some years the rate of advance along the shaft of a long bone is rarely more than half an inch a year

It is sometimes difficult to detect the early stage of malignant change in this condition for the osteolytic malignant process may appear



FIG 77 (a) Paget s disease of the lower end of the right femur An osteoporotic zone is shown in the middle of the articular surface (b) Same case as (a) five weeks later The zone of osteoporosis is now shown to have extended as a large area of destruction—an osteogenic sarcoma

merely like another zone of fibrosis However a translucent area of bone already affected by Paget's disease and shown to be increasing in size must be regarded with the gravest suspicion (see Fig 77) Sometimes osteogenic sarcoma arises at the site of a pathological fracture through Paget's disease it is not clear whether the fracture occurs because malignant change is occurring or the trauma to the abnormal cells during fracture excites malignant change Whatever the facts it is wise to carry out careful radiological scrutiny of the fracture site in such cases so as not to miss the early radiological stigmata of sarcomatous change

(6) Simple Bone Tumours

Simple bone tumours give rise to little difficulty in diagnosis Osteomas are relatively rare and occur only in the skull They consist of dense sclerotic bone and are usually rounded or oval in shape They may project from either the inner or outer table of the skull or may project into an air sinus Tumours of cartilage may be entirely or only partly endosseous or may be completely extra osseous and appear as exostoses They usually appear as part of or arising from the shaft of a long bone The enchondromas appear as well defined though often irregular translucent areas within the medulla causing thinning of the cortex from within usually producing abnormalities of moulding of the bone They rarely contain radiologically visible bony structure though they may have some irregular calcification within them They are common in the phalanges and metacarpals where they are sometimes multiple and may present with a pathological fracture and occasionally occur as a single tumour in a rib where they cause considerable expansion The exostoses or osteochondromas as they are histologically contain far more bone among the islands of cartilage and are seen radiologically to contain bony trabeculae They usually arise near the end of the shaft of a long bone and project in the direction of the pull of the adjacent muscles (see Fig 78) They often have a long narrow pedicle with a cauliflower shaped tip

Haemangioma though not a common tumour may give rise to difficulty in diagnosis They occur most commonly in the vertebral bodies and the bones of the vault of the skull In the spine usually only one vertebra is affected The appearance is one of diminished density with uneven absorption of all trabeculae except those running in the vertical plane the whole having a coarse regular spongiosa with a somewhat honeycombed or bubbly appearance The whole structure of the vertebral body is involved the intervertebral spaces not being affected (see Fig 79) The body does not as a rule collapse There may be a widened paravertebral shadow due to the surrounding venous plexus In the skull in addition to the bubbly appearance produced by the wide inter trabecular spaces they may cause expansion of the outer table of the skull



FIG 78 An osteo chondroma arising from the lower end of the femur projecting in the direction of the muscle pull

Fibromas in bone as solitary lesions are rare apart from ossifying fibroma of the mandible already described under tumours of the jaw As part of the more generalized condition of fibrous dysplasia they occur more commonly but as yet it is uncertain whether this is a true neoplastic process or is due to a fibrous replacement of bone arising



FIG 79 A haemangioma of the vertebral body

from a developmental error Excluding those that arise in the skull the common site is in the shaft of a long bone Sometimes the lesion is well defined but sometimes its edges are not clear cut It occurs within the medulla of the bone and is devoid of normal bony trabeculae and is often described as having a ground glass appearance It usually causes thinning of the cortex from within and may cause expansion of the whole bone Owing to its loss of strength due to lack of bony structure it may bend under weight bearing or normal body activity and bizarre deformities sometimes occur Pathological fracture is not uncommon

Osteoid osteoma is a painful condition that may occur in almost any

bone though the lower limbs are most commonly affected The peak incidence is in the second decade of life and it occurs more commonly in males than females The tumour consists of a central nidus of



Fig 80 An osteoid osteoma affecting the second metatarsal Note the considerable bone reaction round the central osteoporotic nidus

osteoid tissue with a surrounding stroma of vascular fibrous connective tissue It is usually situated in the cortex and around the central nidus there occurs a very considerable osteoblastic reaction producing sclerotic bone for a considerable distance around the focus extending beneath the elevated periosteum as dense consolidated bone and sometimes into the medulla Radiologically it appears as a zone of

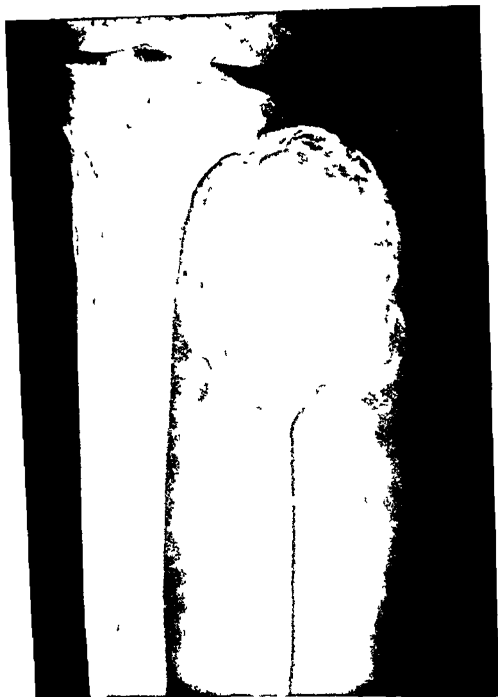


Fig. 81 Osteoclastoma affecting the upper end of the fibula. The great expansion within the tumour pushing out the cortical wall and the clear line of demarcation in the shaft are clearly shown

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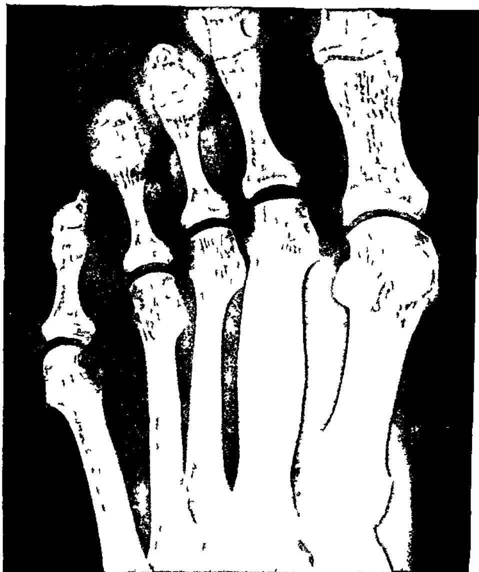


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proximity either to a subjacent osteolytic area or an adjacent area of bone production

The commonest age of occurrence is in the second decade of life

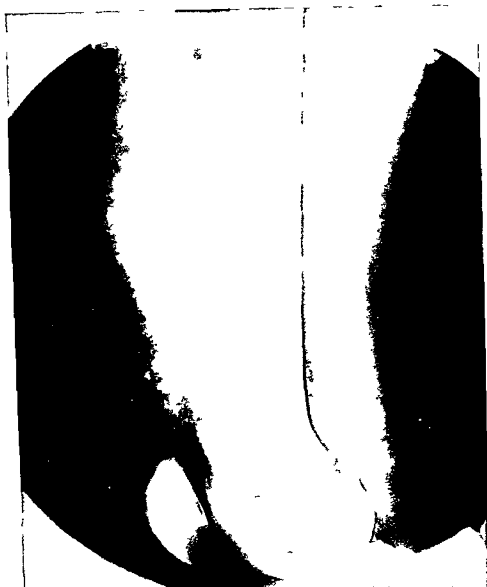


FIG 82 An o teoblastic osteo enic sar oma ari ing in a 14 year old boy The new bone produc tion at right angles to shaft and the periosteal reaction at the edge are well shown

before the epiphyses have united and the commonest site is in the meta physis of a long bone though they may occur anywhere A second peak in age incidence occurs after the age of 60 years some authorities consider that in this latter group it only arises on pre existing Paget s disease but it must be stated that there is not always radiological evidence of this condition

dense sclerotic bone with ill defined edges and with a central less dense focus which is rarely more than a centimetre in diameter (see Fig 80)

Osteoclastoma or benign giant cell tumour is commonest between the ages of twenty and thirty and occurs slightly more frequently in women than in men Most occur in the epiphyses of the long bones Pain of varying severity is almost always the predominating symptom and there is usually swelling of the affected part The characteristic radiological appearance shows as an expanding osteolytic lesion placed excentrically in the end of a long bone of an adult The edge between tumour and normal bone is well defined though no reactive sclerosis occurs (see Fig 81) In some a few coarse strands of bone remain in the osteolytic lesion

Malignant Bone Disease

Primary malignant disease of bone is best classified in simple form the more complex classifications being of histological interest rather than clinical significance Thus most primary malignant tumours in bone fall into one of the following categories

(*a*) *Osteogenic Sarcoma* These may be predominantly osteolytic osteoblastic or cartilaginous histologically they are always mixed all three elements being present but usually one predominates and this influences the radiological picture The osteolytic process destroys bone usually irregularly affecting both medulla and cortex with ill defined edges it often being impossible to say on radiological grounds where the destructive process ends and where normal bone begins The osteoblastic process brings about the production of new irregular bone sometimes within the zone of destruction more often beyond the original skeletal confines of the bone spreading out into the adjacent soft tissues This new bone is sometimes wispy in appearance the strands of bone having no particular pattern sometimes densely sclerotic having a trabeculated but whorled appearance extending into the adjacent medulla and sometimes trabeculated in a radial pattern extending beyond the original cortex perpendicular to the shaft—the so called sun ray spicules (see Fig 82) Though it has found its way into many publications on the subject this latter appearance is not the commonest one in osteogenic sarcoma The cartilaginous element in osteogenic sarcoma may not be apparent radiologically but often calcifies If therefore within a tumour mass exhibiting other significant features there are extensive areas of calcification without trabecular pattern this is probably a manifestation of chondroblastic osteogenic sarcoma

One other common radiological feature in osteogenic sarcoma is a periosteal reaction This often arises some short distance from the tumour increasing in depth as it approaches the tumour edge to end in an abrupt cut off the so called Codman s triangle in close

tumour is radio sensitive and the results of treatment of group (i) are eminently satisfactory of the other two groups less satisfactory though still a practical procedure

Differential diagnosis may be a difficult problem for the clinical presentation is often indefinite and the radiological picture unequivocal The differential diagnosis is usually from an inflammatory process In reticulo sarcoma the cortical and periosteal changes are secondary to medullary changes The condition commences in the medulla as a localized group of small translucencies with ill defined margins these extend along the shaft and become confluent locally Small areas of increased density may be scattered irregularly within the affected bone The cortex is then involved by contiguity in a patchy way later becoming progressively destroyed (see Fig 83) Periosteal new bone may appear with possibly a small reactive triangle of periosteal new bone at the edge of the lesion but as a rule periosteal new bone is not extensive in this condition

In childhood the same appearance may be caused by metastatic neuroblastoma If the lesion is solitary diagnosis may be difficult and it is common for this condition to be labelled as inflammatory in the first instance The solitary lesion is sometimes radio sensitive As the condition becomes more widespread and more bones become in volved the diagnosis becomes more apparent At this stage it is not infrequent to see a more extensive layered periosteal reaction along the shafts of the long bones affected This neoplasm frequently in the later stages metastasises to brain and skull producing a characteristic appearance of widely separated sutures in a calvarium the bones of which show a mottled diminution of density The primary lesion in neuroblastoma often contains calcification and a film of the renal areas showing supra renal calcification may help to establish diagnosis in a case under investigation

(*d*) *Metastatic Carcinoma in Bone* The demonstration and observa tion of metastatic carcinoma in bone is not now such an academic pursuit as once it was for the treatment of multiple metastases from breast prostate and thyroid and solitary metastases from kidney have all met with a measure of success

Metastases from carcinoma of breast are usually osteolytic and are commonly widespread Any bone may be involved but the vertebrae and the ribs are frequently the site of metastases The secondary growth usually starts in the medulla destroying bony trabeculae producing a translucent zone in the bone it increases in size destroy ing cortex by direct spread Pathological fractures through such secondary growths and especially producing compression deformities of the vertebral bodies are common The condition is progressive whole bones being destroyed by the coalescing of adjacent metastases

Arrest of the progress of the destructive process is often observed

(*b*) *Chondro sarcoma* The differential diagnosis between chondro blastic osteogenic sarcoma and primary chondrosarcoma may be difficult or impossible, but is probably only of academic interest Tumours of cartilage in bone are not uncommon, small chondromata or osteochondromata are frequently encountered in the bones of the extremities less frequently in the bones of the trunk Many are of no clinical significance and they cause the patient no trouble Some become clinically manifest merely on account of their mechanical effects such as pressure on adjacent bones and structures A certain few, however undergo malignant change and become chondrosarco mata The commonest site for the simple tumour is in the bones of the hands and feet and these rarely become malignant The most potentially malignant are those round the shoulder girdle and the pelvic girdle Chondroma does not usually grow after the age at which all the epiphyses have united Any cartilage tumour which continues to grow or re commences to grow after that age must be kept under strict clinical and radiological review and any suspicion of malignant change must be dealt with early by local excision or amputation In these cases serial radiography at intervals of time is of the greatest help In any chondroma or osteochondroma which appears to be growing unusually rapidly in childhood or recommences to grow in adult life the radiological sign which indicates malignancy is the destruction of a part of the tumour however small which on previous radiographs was shown to be ossified It is less easy to be certain in the case of endosseous poorly ossified cartilaginous tumours than with the sessile or pedun culated osteochondromata but in the former rapid growth should be viewed with grave suspicion and careful observation be kept for radio logical evidence of local invasion of previously normal adjacent bone

Occasionally primary chondrosarcoma arises without there being any knowledge or evidence of a pre existing simple cartilaginous tumour Often these arise from the pelvic girdle and present as a slowly growing bony hard lump the patient will often complain in the first instance of some mechanical effect or local discomfort they may arise from the outer aspect of a pelvic bone or project into the pelvic cavity Radio logically these usually show as well calcified tumour masses projecting from the parent bone The mass has usually well defined edges and the calcification has a whorled appearance The bone at the site of attach ment may appear normal or may have some sclerotic changes within it or occasionally an osteolytic area which in time may become extensive

Radiological opinion as to whether a cartilaginous tumour is simple or malignant is often more reliable than a histological report on a biopsy specimen

(*c*) *Reticulo sarcoma* This condition may occur as (i) a single primary focus in bone (ii) multiple primary foci in bone or (iii) primary soft tissue reticulo sarcoma secondarily involving bone The

radiologically following adrenalectomy and in some cases consolidation of bony tissue with the laying down of dense abnormal bony trabeculae occurs The gross effect and course following surgery can therefore be assessed alongside clinical improvement

Similarly following radiotherapy or testosterone therapy the arrest and recalcification of osteolytic lesions may be observed and after testosterone therapy dense sclerotic new bone is sometimes laid down in the whole soft tissue mass that was originally metastatic new growth often extending beyond the original confines of bony skeleton

Occasionally metastases from breast carcinoma are osteoblastic at the onset These may be equally widely disseminated but are rarely the cause of pathological fracture

Metastases from carcinoma of the prostate are usually osteoblastic When a clinical diagnosis of carcinoma of the prostate has been made on rectal examination but the serum acid phosphatase remains low confirmatory evidence may be obtained by the demonstration of osteoblastic metastases in the pelvis or spine The arrest of the progress of such metastases under stilboestrol may be assessed radiologically occasionally they have been observed to disappear entirely The differential diagnosis between these metastases and Paget s disease may be difficult but if acid and alkaline phosphatase estimations are unhelpful the opinion of an experienced radiologist will usually prove to be right

Metastases in bone from thyroid may present clinically as solitary lesions shown radiologically to be osteolytic (see Fig 34) Similarly metastases from carcinoma of the kidney sometimes present as a solitary osteolytic lesion in a long bone and some success has been reported by amputation of the affected limb and nephrectomy In this latter condition the primary growth may be silent and the case present as a pathological fracture Such metastases are commonly large osteolytic lesions with well defined edges arising in the medulla eventually breaking the cortex



FIG 83 Single primary reticulo sarcoma of the upper end of the humerus

and the injection is made as rapidly as possible the first film being exposed after 20 ml of medium have been injected and the others subsequently

If the examination is being carried out to demonstrate the peripheral circulation the needle is best inserted at the level of the body of the second lumbar vertebra below the point of origin of the renal arteries all the contrast medium thus passes down the aorta and is not lost in the renal circulation

The indications for the use of this technique in renal conditions are

(i) to differentiate between renal neoplasm and renal cyst, when this is considered clinically essential (N B See renal puncture)

(ii) to investigate cases of hypertension which may be of renal origin

(iii) to investigate cases of renal haematuria when excretion uro graphy and retrograde pyelography have been normal

(iv) to demonstrate the vascular tree of the kidney when partial nephrectomy is contemplated

The indications for its use in vascular conditions are

(i) to demonstrate the site and extent of suspected thrombosis of the aorta or more especially of its main branches

(ii) to demonstrate or exclude suspected aneurysm of the aorta or of its branches

(iii) to confirm the diagnosis of and demonstrate the site of arterio venous fistula

These are discussed more fully in the section on femoral arteriography below

(2) Femoral Arteriography

Although the risks of peripheral arteriography are small the indica tions for its use are few Much information can be obtained by clinical examination and oscillometry and arteriography should only be undertaken when further and more exact information is required which will be of benefit to the patient

The technique is as follows

(*a*) Femoral arteriography is carried out under spinal anaesthesia as this prevents spasm which may otherwise be induced by an injection of contrast medium

(*b*) The injection is made percutaneously A Harris s lumbar punc ture needle with a stilet projecting a few millimetres beyond the point of the needle is used The femoral artery is entered with the point of the needle directed proximally and as soon as it is clear that the needle is in the lumen the stilet is introduced and the needle is threaded up the artery for at least a centimetre It is thus firmly within the arterial lumen and need not be held in place By introducing the needle in a proximal direction there is no possibility that it may be directed into the

CHAPTER 8

VASCULAR INVESTIGATIONS

(1) Aortography

AORTOGRAPHY can be performed either by the translumbar approach or by retrograde femoral catheterization The latter method has been described under Renal Arteriography in the section on the Urinary Tract.

For translumbar aortography the apparatus required is a 15 cm. S W G needle pressure tubing, a 20 ml syringe filled with warm saline and a 30 ml. syringe filled with 70 per cent contrast medium Some means of taking films in rapid succession is required Complicated and expensive serial devices are available but very satisfactory results can be obtained with cassette tunnels and minor modifications to the X-ray table If it is required to demonstrate the renal circulation a simple cassette tunnel incorporating a stationary grid through which four 15 × 12 cassettes can be passed at intervals of 1—2 sec can be used If it is required to demonstrate peripheral circulation, the Bucky tray can be modified to take two films for demonstration of the abdominal part and a long cassette tunnel can be used to show the limb circulation With a team of helpers it is possible by this method to follow the contrast medium and obtain from a single injection a demonstration of the arterial tree from the point of injection to the foot.

The examination is best carried out under general anaesthesia The patient lies in the prone position. The needle is introduced through the skin just below the twelfth rib four fingers breadth to the left of the midline and is directed forwards medially and upwards towards the body of the twelfth thoracic vertebra. On striking this it is withdrawn about an inch and directed more laterally As the needle slides past the vertebral body it enters the aorta. Throughout the procedure of inserting the needle small injections of saline are made to keep the lumen clear When the aorta is entered blood enters the needle and pressure tubing and forces the syringe plunger backwards At this point it is wise to advance the needle point a further eighth of an inch as, if the needle point is lying partly in the aortic lumen and partly in the wall, when the contrast medium is injected, it may go outside the aorta A forceful injection of saline, followed by allowing the syringe plunger to be forced backwards again will confirm the stability of the needle in the aortic lumen

Then with the cassettes in place and the team ready the 30 ml syringe is fitted to the pressure tube the anaesthetist arrests respiration

and the injection is made as rapidly as possible the first film being exposed after 20 ml of medium have been injected and the others subsequently

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profunda femoris with consequent lack of filling of the main femoral artery

(*c*) The syringe is then connected to the needle by a length of pressure tubing to enable the injector to stand out of the range of the X radiation



FIG 84 Femoral arteriogram showing an arterial graft following a tear of the artery due to the fracture of the femur in a 14 year old boy with severe multiple injuries The graft subsequently thrombosed

and 20 ml of 50 per cent contrast medium injected as quickly as possible preferably within 4 sec

(*d*) By means of a cassette tunnel serial films are then taken along the length of the limb thus demonstrating in turn the femoral artery the popliteal artery the tibial arteries and the arteries of the foot

Pressure is not applied to the artery at any time during the injection as compression of a diseased artery together with the injection of

contrast medium may accentuate the liability to thrombosis Light digital pressure for 2 or 3 min after withdrawing the needle prevents the formation of a perivascular haematoma

By this method it is possible to demonstrate

(*a*) Anatomical variations of the vascular tree



FIG 85 Femoral arteriogram showing an arterio venous aneurysm *in the popliteal fossa There is very marked hypertrophy and* dilatation of the femoral and popliteal arteries and the site of the arterio venous anastomosis is well shown

(*b*) Irregularity of contour of the vessels consisting of small pro trusions into the lumen these represent intimal thickening due to atheroma with or without super imposed thrombus and are especially common at the origin of a branch where it may cause a characteristic constriction or nipping

(*c*) Variations in calibre The calibre of the artery may be increased or decreased although the contour retains its normal smooth outline An increased calibre indicates hypertrophy of the vessel such as occurs in collateral branches if the main artery is occluded or in arteries

proximal to an arterio venous fistula Vessels of an abnormally fine calibre may be seen in thrombo angiitis obliterans

(*d*) Changes in the rate of flow

(*e*) Occlusion of an artery This is usually the result of thrombosis secondary to atheroma The thrombosis which appears clear cut on the arteriogram usually spreads proximally to the origin of a branch artery through which the flow is deviated The collateral circulation often dilated and tortuous is usually shown

(*f*) The state of the circulation after arterial graft (see Fig 84)

(*g*) Arterial aneurysm Care must be taken in the interpretation of the appearances obtained for the aneurysmal sac may be filled with laminated thrombus and the radiographic demonstration may show no more than a shallow bud from the lumen of the artery

(*h*) Arterio venous fistula This condition presents one of the most characteristic pictures in clinical surgery and arteriography is not required for its diagnosis It may be a useful procedure however to locate the precise anatomical position of the lesion as an aid to the *surgical approach (see Fig 85)*

Arterial embolus is a condition with a clear and dramatic history and characteristic physical signs Angiography (either aortography or arteriography) is not required in making a correct diagnosis The operation of embolectomy should be performed as soon as possible after the circulation is interrupted and radiological investigation will only impose delay Further though aortic arterial injections are comparatively safe under most circumstances they may cause thrombosis in the stagnant column of blood which exists proximal to a recent block In this condition therefore angiography is considered to be contra indicated

(3) Venography of the Leg

The interpretation of venograms of the leg is attended by many hazards and more than most investigations is dependent on the technique employed Most investigations carried out as they are with a view to possible subsequent surgery are directed towards demonstration of the deep circulation either in cases of varicose veins or post phlebitic ulceration or more rarely in acute deep thrombophlebitis Depending on the technique used non filling of the deep veins may or may not be of significance In many techniques failure to fill the deep veins is of no clinical significance and certainly should not be regarded as unequivocal evidence of deep vein thrombosis

The most satisfactory technique is as follows

(1) The patient lies supine on a cassette tunnel the limb is empty the superficial veins and a crepe bandage is applied the ankle to the groin Tourniquets are applied above the knee and the foot is slightly elevated abo table on a wooden block to take pressure off veins

(ii) Injection of 30 ml of an opaque medium (preferably Hypaque or Urografin) is made into an easily compressible vein in the foot preferably on the lateral side

(iii) Films should be taken simultaneously in both the anterior posterior projection (using the overcouch tube) and the lateral projection (using a portable apparatus)

(iv) After 15–20 ml of medium have been injected films of the lower leg are exposed the above knee tourniquet is released and films of the knee and thigh regions exposed as the injection is completed

This whole procedure with a well practised team will take no more than 30–40 sec

In most cases of varicose and post phlebitic ulceration the deep veins will be found to be patent and so a history of deep thrombo phlebitis is not necessarily a contra indication to radical obliteration of superficial varices These latter are usually a hindrance to an already embarrassed circulation If resection of the femoral vein is contemplated in post phlebitic ulceration venography may demonstrate the replacement of the normal deep circulation by tortuous leashes of incompetent blood vessels Widened deep veins demonstrated by this technique are not necessarily abnormal and should be regarded with reserve Similarly retrograde flow is a normal phenomenon and should not be regarded as an indication for radical ligation It is important to realize that failure to fill any particular veins such as the peroneal popliteal or femoral veins may be due to a failure of technique rather than deep vein thrombosis Deep vein thrombosis is usually likely to be clinically evident rendering venography unnecessary

(4) Portal Venography

Portal hypertension is sometimes due to conditions which are amenable to surgical intervention Such operations as splenectomy spleno renal anastomosis porto caval anastomosis and oesophageal or gastric transection have been carried out with considerable success in many centres Before successful surgery can be carried out it is essential first to establish a diagnosis of portal hypertension then to discover whether the cause is intra hepatic or extra hepatic and finally to decide on the surgical procedure to be undertaken

Some cases pass undiagnosed for many years and may present initially as a haematemesis due to rupture of oesophageal or gastric varices The preliminary investigation of these cases has already been discussed in the section on the Alimentary tract Varices in these sites can often be diagnosed as the cause of haematemesis sometimes in cases of repeated haematemesis thus giving an indication of the underlying pathology and of the possible line of surgical treatment No surgeon will wish to undertake surgery of the portal system even after full clinical and laboratory investigation including liver function

tests, without a full knowledge of the anatomy of the portal system in that particular case

Portal venography by direct injection into the spleen at this stage can provide considerable useful information and is carried out as follows

(i) the procedure is only carried out when the spleen is palpably enlarged and can be steadied by manual compression

(ii) it is carried out in the X ray department where the patient lies on the X ray table

(iii) general anaesthesia is only used when the patient is a young child In older children and adults infiltration of local anaesthesia subcutaneously and into the parietes is carried out

(iv) a wide bore needle and stilet 15 cm long is then inserted into the spleen entering the surface about 4 or 5 cm above the costal margin through a rib interspace usually the 10th or 11th in line with the apex of the spleen Thirty millilitres of concentrated contrast medium (e g 70 per cent diodone 76 per cent urografin) is then injected as rapidly as possible

(v) When the needle is in the spleen the patient is instructed to suspend respiration If general anaesthesia is used the anaesthetist controls respiration

(vi) the first film is exposed as the injection is being completed and serial films subsequently

The contrast medium thus injected into the spleen enters the splenic vein immediately passes into the portal vein and so into the hepatic radicles There is no delay whatsoever in this flow The splenic vein usually has a gentle curve but may be tortuous The site of entry of the superior mesenteric vein can usually be identified by a streaming effect The films taken at intervals after the injection show the small intra hepatic vessels In normal cases the lumen of the splenic vein is usually slightly less in calibre than that of the portal vein

By this method the following may be demonstrated

(i) Splenic vein thrombosis partial or complete

(ii) Anomalies of the portal vein such as mural thrombi narrowing due to re canalization following thrombosis or developmental anomalies such as a cavernous plexus of veins (see Fig 86)

(iii) Intra hepatic portal obstruction with generalized narrowing of the finer vessels

(iv) Collateral circulation secondary to obstructions at these various sites e g by peri splenic veins or by the left gastric vein gastric varices and oesophageal varices or in cases of intra hepatic obstruction by an umbilical vein (see Fig 86) Where reflux down the inferior mesenteric or superior mesenteric veins is shown this indicates obstruction beyond that site

(v) Where surgical intervention in some cases of portal hyper tension has been carried out and some short circuiting operation such

as porto caval anastomosis has been performed the efficiency of that anastomosis can be shown

In cases where splenic vein thrombosis is demonstrated the surgeon may still require to know whether or not a portal vein is present and

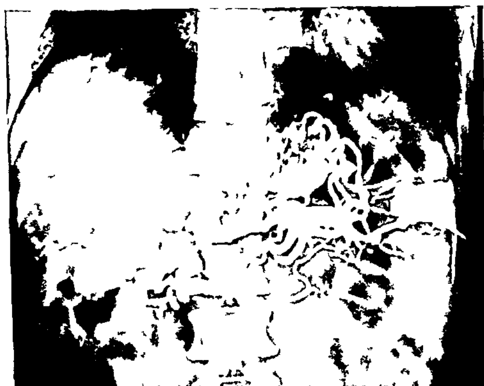


FIG 86 Portal venogram by direct injection into the spleen The portal vein is shown to have been replaced by a plexiform mass of veins the splenic vein is narrow there are peri splenic varices and gastric and oesophageal varices

what its calibre is before attempting to locate it This can only be done at laparotomy by injection of contrast medium into one of the smaller tributaries of the superior mesenteric vein and taking a film or films accordingly Films taken under these conditions in the operating theatre are rarely of the same quality but can be of diagnostic value and can contribute materially to the surgical procedure

CHAPTER 9

PROTECTION

THE increased use of X rays for diagnostic purposes has made pro tection against X radiation an important consideration Radiologists and radiographers are trained to *practise routine protection methods* in their normal daily work and the greater danger probably arises in relation to casual users and to patients

(i) The danger to casual users lies mainly in receiving direct radiation which over the years is cumulative and may produce radiation effects These effects may be leukaemogenic or carcinogenic causing eventually the development of malignant changes in that individual or gonadal bringing about genetic mutations in the germ cells

Surgeons may fall into the category of casual users especially if they are in the habit of carrying out such procedures as arteriography Smith Petersen pin operations operative cholangiography or other operative procedures requiring X ray control

The code of practice to adopt should be

(*a*) Never allow any part of the body and especially the hands to be in the direct X ray beam during an exposure

(*b*) Avoid scatter radiation as far as possible preferably by standing at least 6 ft away from the direct X ray beam during an exposure

(*c*) If in the habit of conducting many examinations where some exposure from scatter radiation cannot be avoided for example operative cholangiography ask the radiologist to test the dose of radiation being received

It is considered that a person exposed occupationally to this form of ionizing radiation may be permitted to receive up to a tolerance dose of 0 3 r (rontgens) per week This merely means that to keep within this dose is considered safe but the aim should always be to reduce the dose received to a minimum

It should also be remembered that in some operating theatres some *of the permanent staff such as a theatre orderly may receive more* constant exposure than visiting surgeons and if it is the custom to do routine X ray work in the theatre such staff should have continuous monitoring of their dose rate undertaken by means of a pocket ioniza tion chamber or a standard film exposure service

(ii) The danger to patients is mainly the cumulative effect on the gonads which may produce genetic effects not apparent immediately but which only produce their biological results in the second and third generations

The dose to the gonads arises in such examinations as X ray of the lumbar spine (in females) pelvis hip excretion urography barium enema etc A Medical Research Council Report in 1956 recommended that

(a) during his whole life time a person should not be allowed to accumulate more than 200 r of whole body radiation in addition to that received from the natural background and this dose should be spread over tens of years

(b) a person should not be allowed to accumulate more than 50 r of radiation to the gonads in addition to that received from the natural background from conception to the age of 30 years and this dose should not apply to more than one fiftieth of the total population of the country

With this in mind it is worth remembering that the dose in milli rontgens administered to the gonads in routine examinations while obviously it must vary from department to department is probably of the order

	Male	*Female*
Abdomen	70	200
Urography	500	1300
Lumbar spine	130	700
Pelvis	1100	200
Barium Enema	500	500

Repeated examinations in the treatment of conditions like con genital dislocation of the hip or lumbar scoliosis in a young girl will soon build up a significant cumulative dose This emphasizes the responsibility of those concerned with such work The responsibility of the radiologist and his staff is to conduct the examination efficiently producing a diagnostic result if possible with the minimum exposure to the patient The responsibility of the clinician who requests an X ray examination must be to have a clear conception in his mind what useful information is likely to be derived from the investigation and to consider that this particular information is essential to the patient s welfare and to his management of the case at that particular time